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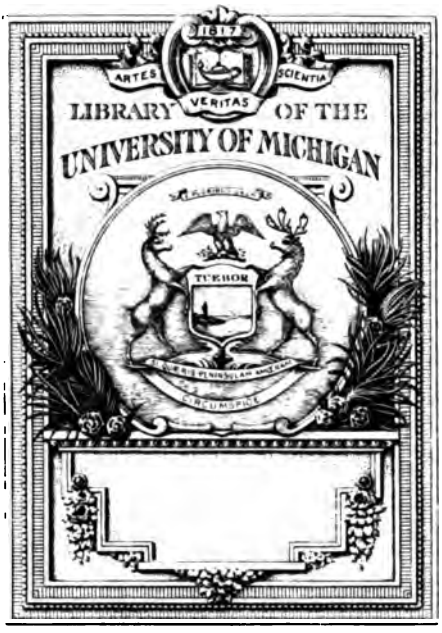
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MEMOIRS OF THE GEOLOGICAL SURVEY.

# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

OF

# GREAT BRITAIN

AND THE

# MUSEUM OF PRACTICAL GEOLOGY

FOR

# 1906.

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# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

AND

# MUSEUM

FOR 1906.

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## *INTRODUCTION.*

By J. J. H. Teall, M.A., D.Sc., F.R.S., Director.

In England and Wales field-work has been continued in Cornwall, South Wales, and the Midlands; while in Scotland progress has been made with the original survey of the Northern and Western Highlands, and with the revision of the Carboniferous areas of the Midland Valley.

**Highland Metamorphic Rocks.**

In the North Highland district the work of separating the pelitic from the siliceous schists of Moine type and of both from rocks allied to the Lewisian gneiss has proceeded on the lines laid down in previous Summaries. During the year further evidence of the association of crystalline limestone and graphite schist with rocks of Lewisian gneiss type has been obtained in Glen Strath Farrar.

The detailed mapping of the schists brings out the complicated nature of the folding to which they have been subjected, and the results obtained in the neighbourhood of Beinn Dronnaig, which are described and illustrated by a sketch map, will give some idea of the nature of these disturbances and the structural features resulting therefrom.

Further progress has been made with the mapping of the schists in the West Highland district; but, as the work proceeds, the difficulties of interpretation and correlation appear to increase rather than diminish. Notwithstanding the fact that a large part of the Southern Highlands has now been surveyed, no general theory as to the structure or sequence of rocks has been formed on which all officers are agreed. Under these circumstances it becomes necessary to eliminate theory as far as possible from the maps, and to confine the official work to the representation of the distribution of the different kinds of rock.

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**The Lizard District.** The re-survey of the Lizard district on the six-inch sc was commenced during the year. As is well known, it is region of massive rocks and crystalline schists, and much d cussion has taken place as to the relation of one to the oth It is too early yet to say whether the re-survey will result a solution of any of the unsolved problems. So far as t actual mapping is concerned, the boundaries of the serpenti and hornblende schist, as laid down on the old one-inch ma have not been greatly modified, but the 'granulitic serie which was first recognized as a distinct group by Profess Bonney, has been found to occupy a larger area than h hitherto been suspected. The representation of this group, far as it can be ascertained, will constitute the most striki difference between the old and the new one-inch maps. I teresting evidence of contact-alteration has been detected the metamorphosed sediments of Polpeor and Old Liza Head.

**Lower Palæozoic.** In Cornwall the mapping of the sedimentary rocks on t north side of the Lizard area has been completed with t exception of a small area near Gunwalloe, presumably occ pied by Devonian rocks, and the four divisions—Verya Portscatho, Falmouth, and Mylor—have been traced acro the country from east-north-east to west-south-west. T Mylor series lies to the north and the other sub-divisions follo in regular order towards the south. Owing to the intrica folding and the absence of sharp lines of demarcation betwe the different sub-divisions, the boundary lines have on a certain general value, and do not reveal the details of t complicated structure. Although the dominant movemen to which the prevailing strike in West Cornwall is due a of post-Devonian age, evidence has been obtained in th district of important movements affecting the Lower Palæozo but not the Devonian rocks.

The boundary between the typical Lizard rocks and th Palæozoic rocks to the north has been traced with some in teresting results, the significance of which will have to be car fully considered when the whole of the Lizard area has bee mapped. On both coasts the junction is a faulted one, bu inland, for a considerable distance, it follows an irregular lin which is difficult to explain by any system of faults.

In South Wales the work of surveying the Lower Palæozo rocks which come within the one-inch sheets of the coal-fiel has been continued. No new type of structure has been me with, but an important change has been made in the positio of the line separating Bala from Llandilo, mainly in conse quence of assistance derived from Miss G. L. Elles. On com paring the vertical succession of Ordovician rocks given i last year's Summary with the corresponding succession in th present Summary it will be noted that this line is now draw in the middle of the *Dicranograptus* shales. This change ha been rendered necessary by the recognition of several well known graptolitic horizons, some of which belong to th

Glenkiln, while others belong to the Lower Hartfell group of the typical Moffat section.

Devonian.

In South Cornwall the Manaccan beds, which have been referred to the Lower Devonian, form a series of outliers of no great extent in the area north of the Serpentine tract of the Lizard. They consist of conglomerate, sandstone, and clay-slate, and the conglomerate is largely composed of detritus from the Portscatho and Veryan groups, together with fragments of granitic and metamorphic rocks.

In North Cornwall the work of separating the Lower, Middle, and Upper Devonian rocks has been proceeded with, and incidentally much information has been obtained as to the metamorphic action of the granite, and of the vapours or solutions containing boron and fluorine, which were given off during the final stages of plutonic activity. Near Roche, on the north side of the St. Austell mass of granite, the tourmalinization of both granite and sediments is well illustrated. In the same neighbourhood, and also further to the north, certain impure calcareous beds belonging to the Meadfoot series of the Lower Devonian take on the character of hornstones, and in this state, owing to their superior hardness, stand out prominently above the surrounding killas. Where these hornstones have been affected by the pneumatolytic action, axinite has been developed on an extensive scale. The representation of these bands will form a new and important feature on the one-inch geological map of the district. They are quarried for road-metal in more than one locality.

The granite moors of Bodmin and St. Austell were formerly important localities for stream-tin, and some interesting particulars as to this very ancient industry will be found in the following pages.

The Old Red Sandstone facies of the Devonian has been studied in South Wales and in Caithness.

Carboniferous.

Much work has been done on Carboniferous areas both in England and Scotland. The tracing westward of the Carboniferous Limestone in Pembrokeshire, on the north side of the coal-field, has furnished additional evidence of the breaks in the sequence to which reference has been made in previous Summaries. The Lower Limestone shales (Clevedonian) disappear about three miles west of Templeton, so that the *Seminula* beds (Kidwellian) here rest directly on the Old Red Sandstone. Further west, between the two Cleddaus, the total thickness of the limestone is less than 50 feet, and at Haroldston St. Issels, about one and a half miles south-south-east of Haverfordwest, the Millstone Grit rests unconformably upon a limestone belonging to the *Seminula*-zone. The remarkable attenuation of the Carboniferous Limestone as it is traced westward from Pendine is therefore due to (1) an overstep of the Kidwellian on to the Old Red Sandstone, and (2) to an overstep of the Millstone Grit on to the lower part of the Clevedonian.

The mapping of the Carboniferous limestone on the south

side of the Pembrokeshire coal-field has brought to light an interesting break in the middle of the *Syringothyris*-zone. The *Caninia* oolite, which is the uppermost member of the lower subzone, had been piped, corroded, and partly removed before the overlying shales with rubbly limestone belonging to the upper subzone were deposited. This break, though occurring on a slightly lower horizon, is no doubt connected with the break at the base of the Kidwellian on the north crop. A comparison of the phenomena seen on the opposite sides of the Pembrokeshire coal-field shows that after the emergence, as proved by the break, deposition commenced earlier in the south than in the north; or, in other words, that the succeeding wave of depression travelled from south to north.

The mapping of the Coal-measures in Pembrokeshire is attended with great difficulty, in consequence of the intense disturbance which has taken place. Although the details cannot in all cases be made out, the general effect of the movements is well seen in the coast section on the east and in the low cliffs which border the estuary of the Eastern Cleddau, and of the Daucleddau in the west. The beds are often overfolded and over-thrust from the south, so that although the prevalent dip is to the south, the general sequence in this direction is a descending one, the Millstone Grit being thrust over the Coal-measures, the Carboniferous Limestone over the Millstone Grit, and the Old Red Sandstone over the Carboniferous Limestone. These phenomena, as they are seen on the shores of the Eastern Cleddau and of the Daucleddau, are described in the following pages. Near the southern end of the section there described 'for a space of about 50 yards the softer strata are sheared to a schistose mass, in which are embedded angular lumps of quartzite, sandstone, and ironstone, forming a typical crush-rock. At one part in this crushed belt occur three huge boulders of the white quartzite of the basal part of the Millstone Grit series. One of these is cylinder-shaped, and is completely surrounded by a sheared mass of shale.' These phenomena are similar to those seen in the Gorran-Vervan district of Cornwall, where Ordovician quartzites and shales have been subjected to similar stresses.

The re-survey of South Pembrokeshire has brought to light east and west faults which are entirely unrepresented on the old map. One of the most important of these, now known as the Ritec fault, has been traced continuously from Carmarthen Bay at Tenby to the shore of Milford Haven at Pembroke Dock. It increases in throw westward, and near Pembroke Dock brings the higher zones of the Carboniferous Limestone in contact with a part of the Lower Old Red Sandstone which lies far below the Ridgeway conglomerate. The throw at this point must be at least 2,000 feet, and may be considerably more.

We pass now to the Midland district. In the Chesterfield area the mapping of the sandstones which were neglected at the time of the original survey has been continued. They

are, as a rule, impersistent, and no doubt represent small local sand-banks. Careful attention has been paid to the possibility of the occurrence of important workable coals below the well-known Silkstone seam, but the results are distinctly discouraging. The seams above the Silkstone, many of which exceed two feet in thickness, are therefore regarded as far more likely to yield profitable results in the future than the more irregular seams which occur below that horizon.

During the year a comparison has been made of the vertical sections disclosed during boring and sinking operations through the red rocks in the concealed part of the Nottinghamshire coal-field. The records are not as complete as could be wished, but such as they are they throw doubt on the generally accepted correlation of some of the seams. The point involved is of great importance, and it is much to be regretted that the evidence available is insufficient to settle the question. I desire once more to emphasize the fact that when borings or sinkings are carried out records should be kept not only of coal-seams and the more striking lithological features, but also of any fossiliferous horizons. The fossils, whether of plants or animals, should be carefully preserved and submitted to experts for determination.

In Scotland the revision of the Carboniferous areas was continued in the Coatbridge and Motherwell district, and in the Glasgow and Denny district. The revision of North-East Lanarkshire has led to some important changes owing to the adoption throughout the district of the Castle Cary limestone as the top of the Carboniferous Limestone series, but these changes do not imply any difference of view between the earlier and later observers as to the structure of the district.

Trias. This formation has been met with in that portion of Nottinghamshire which is included in the new series one-inch map (Sheet 142). The sub-divisions surveyed during the year include the Keuper Marl and the Rhætic beds. Gypsum is found within the area surveyed, but the most productive works occur beyond the northern and western boundaries of the map. In the original map the occurrence of Rhætic beds in the district was not indicated, and the 'tea-green' marls were taken as the base of the Lias. In the re-survey the boundaries of both these formations have been traced, and as both are referred to the Trias the line which represents the base of the Lias does not correspond with the line as laid down on the old map.

Lias. The three divisions of the Lias—Lower, Middle, and Upper—have been surveyed in Sheet 142 (England), and the lithological characters of the different zones have been noted. At or near the top of the *Semicostatum*-beds a fairly persistent sandy bed has been mapped in the Vale of Belvoir. It supplies water to the villages situated along its outcrop, so that the accurate representation of its distribution is of some local importance from the point of view of water supply.

The upper or Marlstone division of the Middle Lias forms

an escarpment, and is of consequence as yielding an ironstone which has been and still is being worked as an ore. The oxidized portion of the bed is the more valuable; but the carbonate is also worked and used as a flux with other ores. The Marlstone has been found to extend further westward than is represented on the old map.

sic. The Northampton Sandstone and Ironstone, with the overlying Lower Estuarine series occur in Sheet 142, and so also does the Lincolnshire Limestone; but no new facts of importance with reference to these formations have been brought to light during the re-survey of the small area occurring in this sheet.

ocene Recent. The superficial deposits have been surveyed in all regions in which work is going on. The revision of those portions of Nottinghamshire and Leicestershire which are included in Sheet 142 is of special importance, for the boulder-clay which is unrepresented on the old map over the greater portion of the area included within this sheet attains a thickness of over 100 feet in some places, and entirely conceals the older formations over large tracts. The new edition of the one-inch map will therefore be the first geological map in the full sense of the term that has ever been published of this district.

In previous Summaries the occurrence of a comparatively driftless area to the north in Sheet 126 (Nottingham) has been referred to. This area extends into Sheet 142 (Melton Mowbray), so that the work of the year has afforded an opportunity of studying the relation of this tract to the glaciated and drift-covered areas lying to the east and south. The result has been to show that although it is comparatively free from drift it cannot wholly have escaped glaciation; but for the discussion of this and other questions relating to the drifts of this interesting region the reader is referred to the following pages and to the forthcoming memoir.

The great interest which is now being taken in the improvement of agricultural education has led to a consideration of the bearing of the work of the Geological Survey on Agriculture. In December, 1905, a conference was held between representatives of the Agricultural Educational Association and of the Geological Survey, and as a result of this conference Mr. A. D. Hall, Director of the Rothamsted Experimental Station, and Professor T. H. Middleton, of Cambridge, visited the Midland district while the field-work was in progress during 1906, for the purpose of testing the relationship between the geological boundaries and the soils. The results are not yet available; but it is believed that the intercourse in the field will in any case be beneficial as tending on our part to a clearer understanding of the requirements of the agriculturists, and on theirs as to the methods of mapping which we adopt and which are possible under existing circumstances.

Much work has been done on the drifts of the other areas in which surveying is in progress, but for further information on this subject the reader is referred to the following pages.

# I.—ENGLAND AND WALES.

## I.—FIELD-WORK.

The ground to be surveyed was arranged in three areas as follows:— Mr. Woodward.

1. Midland district under Mr. G. W. Lamplugh.
2. Southern district under Mr. C. Reid.
3. South Wales district under Dr. A. Strahan.

The examination of the cuttings on the Clarbeston and Goodwick Railway, begun by Mr. H. H. Thomas in 1904, was continued by him and Mr. O. T. Jones in 1906.

In addition to the ordinary field-work Mr. W. Gibson examined the rocks from shaft-sinkings and deep-borings in progress at various localities in the area of the North Midland Coalfields.

### 1.—Midland District—Derbyshire, Nottinghamshire, and Leicestershire.

Mr. G. W. Lamplugh, F.R.S., District Geologist.
Mr. W. Gibson, B.Sc.
Mr. C. B. Wedd, B.A.
Mr. R. L. Sherlock, B.Sc. } Geologists.
Mr. B. Smith, M.A.

The field-work of the year was concentrated upon Sheet 142 (Melton Mowbray), and the survey of this sheet was completed. Some progress was also made in Sheet 112 (Chesterfield), in the Derbyshire Coalfield, by Mr. W. Gibson.

#### *Derbyshire.*

##### CARBONIFEROUS.

*Matlock District.*—Mr. Wedd paid a short visit to this district at the end of the field-season to gain information respecting the recently improved conditions of the mining industry. Mr. Wedd

Until recently the ancient industry of lead-mining in Derbyshire had entirely lost its former importance, and indeed had almost ceased to exist. Lately, however, that industry has experienced a great revival; while at the same time the mining of fluorspar for commercial purposes is now assuming an importance it has never possessed before.

Farey* and others have published much information concerning the manner of occurrence, and the mining, of lead and other minerals in Derbyshire in the past, and a somewhat detailed account of the subject will be found in a former memoir of the Geological Survey on this district.†

* "General View of the Agriculture and Minerals of Derbyshire" (1811).
† 'Geology of the Carboniferous Limestone, Yoredale Rocks, and Millstone Grit of North Derbyshire," Ed. 2 (1887).

The occurrence of lead-ore and fluorspar may be said for all practical purposes to be confined to the Carboniferous Limestone in Derbyshire; though the lead-veins run occasionally into the Limestone Shales ("Yoredale" Shales), and may even be found in the Millstone Grit, while lead has been met with in minute quantities in the Coal-measures.

Both minerals are accumulated chiefly in joints, fissures, and other cavities in the limestone.

We are indebted for the following information on the occurrence and commercial aspects of fluorspar and lead in Derbyshire to Messrs. Drabble Bros., of Matlock, who have a wide practical knowledge of the subject.

*Mode of occurrence of Fluorspar.*—Messrs. Drabble suggest the appended classification of the principal modes of occurrence of fluorspar*:—

(*a*) Rake-veins: deposition in enlarged joints, faults, fissures, or cracks. In the last-named case the veins are known as scrins.

(*b*) Pockets: deposition in chambers on the side of a rake.

(*c*) Pipes: the combination of joint or fault-cavities with one or more horizontal cavities formed along the bedding, the whole being more or less completely infilled with mineral ore.

*Distribution of Fluorspar in the Carboniferous Limestone.*—Fluorspar never occurs far from the margin of the limestone outcrop. Even in rake-veins that run far across the limestone, fluor only occurs in the outer end of the rake (see the case of the Shuttle Rake, "Geology of the Carboniferous Limestone, &c., of North Derbyshire," Ed. 2., p. 132; also the White Rake, *ibid.*, pp. 132 *et seqq.*). It is notable, too, that the districts in which fluor occurs are all on the *eastern* edge of the limestone *massif*.

It is a dictum of the miners that wherever you find fluor you find lead; but the converse does not hold. The "gangue" in the majority of the mines and rakes is calcite or barytes, or both in conjunction.

The districts in which fluorspar is met with in the Derbyshire mining-field may be grouped as follows;—

(I.) Bradwell.
(II.) Eyam, Longstone Edge, and Hassop.
(III.) Matlock, Cromford, and Bonsall.
(IV.) Ashover, (V.) Crich } Fluor is more consistently strong in the mines in these inliers of the limestone than elsewhere.

*Mines re-opened.*—The following are some of the principal

* A slightly different classification was given in the Survey memoir, "Geology of the Carboniferous Limestone, &c., of North Derbyshire," Ed. 2 (1887), pp. 121-2.

mines that contain fluor in commercial quantities, and have been re-opened:—

(I.) Bradwell district:—Shuttle Rake (Intake Dale Mine eastwards), Moor Furlongs, Virgin, and other mines.
(II.) Eyam district:—New Grove, Slater's Engine, Lady-wash, and others near Eyam and Stony Middleton; also Sallet Hole, Backdale, Deep Rake, and Red Rake, &c., near Hassop and Longstone.
(III.) Matlock district:—The Oxclose (near Snitterton), the Dale and High Loft (or Knowles) Mines at Matlock; the Coalpit Rake, &c.; the Bullestree and Mole-Trap Mines at Cromford.
(IV.) Ashover:—The Gregory, Overton, and Blackland Rake Mines are notable.*
(V.) Crich:—All the mines in this inlier are richly productive of fluor of special quality, notably the Glory, Church, Hope, Bacchus, Pearson's Venture, and Plaistow Field. The gangue of all the mines in the Crich district consists almost entirely of fluorspar.

*Distribution of Lead.*—Lead is more widely distributed than fluor in the Derbyshire limestone, and occurs wherever fluor is found.

*Commercial Grades of Fluorspar.*—Fluorspar is put on the market in two grades, viz., "lump-spar," as the spar got direct from the mines is termed, and "gravel-spar." The latter consists of the tailings from the old ore-dressings, and contains from 55 to 75 per cent. of calcium fluoride. These tailings are screened from the old "hillocks." The "lump-spar" has in general some slight impurities in the shape of calcite, barytes, &c., and when dressed for market averages from 90 to 95 per cent. of calcium fluoride, anything above 95 per cent. being exceptional.

*Commercial Uses of Fluorspar.*—Commercial fluor, both lump and gravel, is very largely used for fluxing in iron and steel foundries, more particularly abroad. Smaller quantities are employed for the same purpose in this country. Fluor from Crich was much used in the Butterley and Somercotes furnaces in 1800 as a flux for the ores (Farey, *loc. cit.*).

Fluorspar ("lump-spar" only) is also employed for making hydrofluoric acid, and in glass-works, copper-smelting-works, &c. Farey states (*op. cit.*, vol. i., p. 461) that large quantities were got from the High Loft or Knowles Mine at Matlock in 1800, and taken to Ecton in Staffordshire for copper-smelting.

*Market Value.*—The value of "lump-spar" at the mines is from 11s. to 14s. a ton, according to quality. The value of the "gravel" screened from the "hillocks" would be rather less than half as much.

* See Farey, "General View of the Agriculture and Minerals of Derbyshire," vol. i. (1811), p. 461, and "Geology of the Carboniferous Limestone, &c., of North Derbyshire" (*Mem. Geol. Surv.*), Ed. 2 (1887), p. 163.

*Output of Fluorspar and Lead-ore.*—The following figures are taken from the Home Office report*:—

| | Tons. |
|---|---|
| Output of fluorspar for Derbyshire in 1905 ... ... | 34,457 |
| „ „ lead-ore „ „ „ „ ... ... | 5,249 |

These figures show a great increase over the previous year in the case of fluorspar. Messrs. Drabble state that the present annual output of fluor for Derbyshire (December, 1906), would be at the rate of at least 50,000 tons, and of lead-ore at the rate of 10,000 tons.

*Reasons for Revival of Lead- and Fluor-Mining.*—The market price of fluor is not sufficiently high to bear the cost of mining operations for it alone; but in Derbyshire, the mines were originally opened and wrought for lead, and the fluor was merely a by-product, now of commercial value. The increasing use of fluorspar in smelting, particularly abroad, and the difficulty in obtaining a cheap local supply are the main causes for the re-opening of the Derbyshire mines. In these mines a great quantity of fluor is stored in the "gob" of the old lead-workings. Under present conditions, when both the fluorspar and the lead can be marketed, and when, moreover, the price of lead has advanced considerably from its previously low level, the prospect for the profitable working of the Derbyshire mines has greatly improved.

The cessation of lead-mining in Derbyshire was due to the great fall in the value of lead, not to the exhaustion of the mines; but the advance of the price to its present level is inducing the re-opening of mines for lead alone, and the demand for fluorspar is a further stimulant to the industry.

*Lead-Mines Re-opened in the Wirksworth District*:—

| | |
|---|---|
| Newton Grange | Success. |
| | Plashy Cliff. |
| | Nancy. |
| Middleton ... | Watering Pools. |
| | Slack Rake. |
| | Welshman. |
| | Whippit. |
| Brassington | Conway. |

At Matlock the Seven Rakes Mine has been re-opened. In the Crich district the fluor-mines are also producing lead.

## *East Derbyshire and Nottinghamshire Coalfield.*

### COAL-MEASURES.

### *Chesterfield District.*

Mr. Gibson. The lowermost portion of the Coal-measures between the Silkstone Coal and First Grit of the Millstone Grit Series in

* "Mines and Quarries: General Report and Statistics for 1905," Part III (1906), pp. 206–7 and 238.

the area south-west of Chesterfield was examined and mapped. These measures assume some importance since their exploration is likely to be undertaken as the more valuable seams above the Silkstone Coal approach exhaustion. In the present area, owing to the repeated undulations of the strata, it has not yet been found possible to calculate the thickness between the above-mentioned horizons, but it is likely to exceed 1000 ft., as some of the individual beds, even when highly inclined, often cover a considerable area. The rocks consist of repeated alternations of shales and sandstones, the latter attaining greater prominence than in the Middle Coal-measures. Here, as elsewhere in the Midlands, it has not become practicable, either on lithological or palæontological grounds, to recognize definite sub-divisions in this thick succession of strata. In the country south of Chesterfield, the lower part contains a marine bed above the seam known as the Alton Coal—between 200 and 300 feet above the First Grit; but neither this horizon nor the accompanying coal-seam has been detected in the area here dealt with. While their apparent absence may possibly be due to failure of exposure on the exact horizon, Mr. Gibson is inclined to think that, even if the horizon be present, it is locally unfossiliferous, as several streams afford fairly clear and continuous sections near its supposed position. In fact, the entire sequence between the Silkstone Coal and First Grit is cut through and admirably exposed in numerous stream sections, and though close search was made for any distinctive fossil band, it was without result. This general absence of fossils in this part of the Coal-measures is in accordance with the experience obtained along the outcrops of these measures throughout the Midlands; but in this area even the marine horizon which elsewhere affords a reliable datum seems to be wanting. The new sinkings at Denby Colliery, however, prove that the so-called "mussel bands" do exist, but in this sinking no marine bed other than that above the Alton Coal was found.

Between the Alton Coal and the Silkstone, the only known workable seam is the Kilburn Coal, which is an important coal in Southern Derbyshire, but has not been worked north of Pye Bridge. This seam is probably represented in the present area by the Brampton Lower-Bed Coal, formerly worked at the Old Brampton Colliery, 30 chains south-west of Old Brampton Church. The section of this shaft on an old plan preserved at the Home Office is as follows:—

SECTION OF OLD BRAMPTON COLLIERY.

| | Ft. | In. |
|---|---|---|
| Ratchel ... ... ... ... ... ... ... | 12 | 6 |
| Rock ... ... ... ... ... ... ... | 26 | 0 |
| Bind ... ... ... ... ... ... ... | 20 | 6 |
| COAL (Brampton Lower Bed) ... ... ... ... | 1 | 9 |

The thickness of this coal compares very unfavourably with that of the Kilburn Coal of Southern Derbyshire and Leicest[redacted]

shire; and no other seam, more than a few inches thick, is known, or has been detected by Mr. Gibson, in the present area. Therefore, such information as we have obtained up to the present is not encouraging to the prospects of getting workable seams below the Silkstone Coal in the Chesterfield area. It appears to Mr. Gibson, indeed, that the still unworked seams, many exceeding two feet in thickness, which lie above the Silkstone Coal and occur at intervals throughout the Middle Coal-measures, are far more likely to give profitable results than the lower and more irregular seams below the Silkstone Coal.

*The Eastern Extension of the Nottinghamshire Coalfield.*

In the Summary of Progress for 1904 especial attention was drawn to the importance of securing accurate and intelligible descriptions of the strata passed through in the new sinkings and borings for coal beneath the Red Rocks of the Midlands. The necessity for a correct and complete knowledge of the character of the Coal-measure strata above the Top Hard Coal of Nottinghamshire has been recently forced upon us in the preparation of a Survey Memoir dealing with the geology of the country around Nottingham and Newark.

The Triassic Rocks occur at the surface over the whole of the eastern part of this area, but up to the present time only two attempts have been made to prove the Coal-measures beneath them. These are, the boring at Thurgarton, three miles south of Southwell: and the workings of the Gedling Colliery, three miles north-east of Nottingham City. The boring at Thurgarton yielded negative results as regards the exact horizon attained in the Coal-measures at the total depth of 2,239 feet.

The shafts of the Gedling Colliery are considered to have reached the Top Hard Coal at a depth of 1,378 feet, but the thickness of the seam was found to be less than that of its supposed equivalent at Bestwood Colliery $3\frac{3}{4}$ miles to the north-east of Gedling. However, if we assume that the Top Hard has been correctly identified, a considerable discrepancy exists between the sequence at Gedling and that at Bestwood.

In the shafts of the Gedling Colliery the Coal-measures immediately underlying the Magnesian Limestone consist of 100 feet of red marls. The same red measures were passed through at Thurgarton, and were there conclusively proved (Summary for 1902, p. 14) to be identical with the red marls we find lying conformably on the top of the productive measures throughout the Midlands (with a possible and unexplained exception in the Coalbrookdale Coalfield).

Now on comparing Gedling with Bestwood, it is found that the shafts at Bestwood entered the Coal-measures below the horizon of these red marls, and yet over 1,000 feet of grey productive Coal-measures lie above the Top Hard Coal at Bestwood, as compared with 750 feet of grey productive measures above the seam considered to be the Top Hard at Gedling.

Therefore, at Gedling at least 250 feet of grey measures are missing and require to be accounted for.

The problem possesses four possible solutions:—

(1). The unconformity of the red measures. (2). The attenuation of the grey productive measures between Bestwood and Gedling. (3). Faulting at Gedling. (4). The incorrect identification of the Top Hard Coal at Gedling.

(1). *The Unconformity of the Red Measures.*—If the red measures are unconformable at Gedling, their invariable conformity throughout the Midlands is here broken for the first time. There is, however, some palæontological evidence for their conformity at Gedling, since they are here directly underlain by the zone of *Anthracomya phillipsi*, as they are elsewhere in the Midlands. Stratigraphical evidence of their conformity is also not wanting, for while the red measures are invariably met with in the eastern or deeper parts of the Nottinghamshire and Yorkshire Coalfields they are absent in the west, that is, towards the rise. An unconformity is nevertheless possible, but receives no support from the evidence at present available.

(2). *Attenuation of the Grey Measures.*—A comparison of the shaft-sections of Bestwood, Hucknall, and Linby shows a general but slight attenuation of the grey measures from north to south, but the rate is very much less than 70 feet per mile, which is the amount necessary to account for the 250 feet difference between the thicknesses at Gedling and Bestwood.

(3). *Faulting.*—A fault by cutting out some 250 feet of grey measures at Gedling would account for the discrepancy; but the identity of the sequence in the two shafts and the information gained in the underground workings precludes the existence of a fault having the required amount of throw.

(4). *Incorrect determination of the Top Hard Coal at Gedling.*—A solution of the difficulty could be obtained by assuming the supposed Top Hard Coal of Gedling to be other than the seam known under this name at Bestwood and elsewhere in the Derby and Nottinghamshire Coalfields.

If we venture to take the Clowne Coal of Bestwood to be the High Hazles Coal of Gedling, the two shaft sections will be seen to bear a considerable resemblance to each other in many points of detail, while the apparent discrepancy between the thickness of the measures vanishes. It can also be calculated that a dip of 1 in 40, which is slightly less than the average inclination of the strata in the Gedling workings, would cause the red Coal-measures to crop out beneath the Permian before reaching the shafts of the Bestwood Colliery.

The agreement in the positions of the thin seams of coal above and below this datum line is certainly considerable.

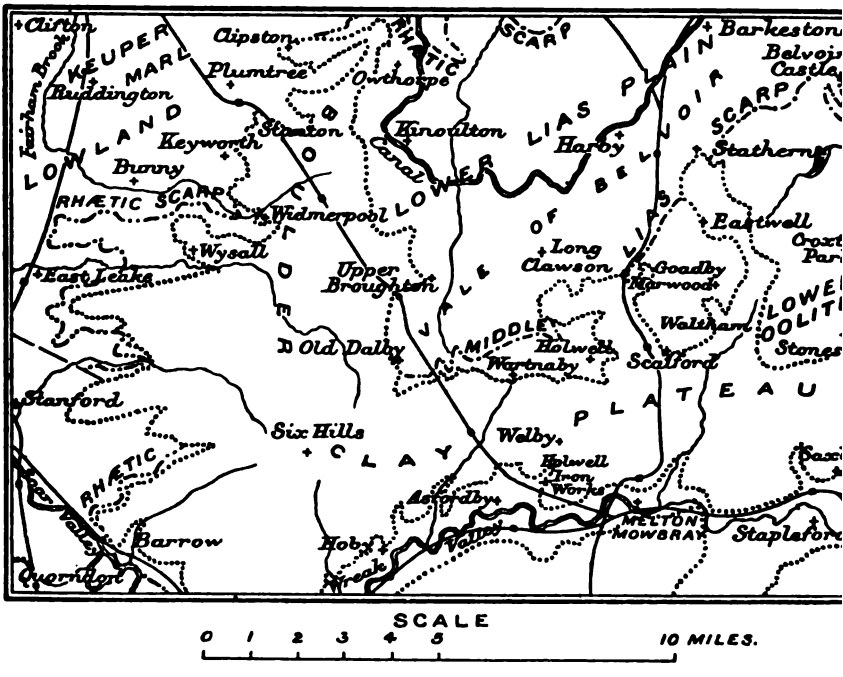
*Nottinghamshire and Leicestershire.*

*Melton Mowbray District.*

**Mr. Lamplugh.**

A strip covering 46 sq. miles in the south-western part of Sheet 142 (Melton Mowbray), between Barrow-upon-Soar and Melton, had been already surveyed by Mr. C. Fox-Strangways and was referred to in a previous Annual Report.* The remainder of the sheet (170 sq. miles) was surveyed during the past year; and as the publication of the map and memoir has now been taken in hand, only a brief outline of the results of the work is requisite here. The area recently

FIG. 1.—*Area of Sheet 142 (Melton Mowbray).*




examined extends from the Trent at Clifton on the north-west to Belvoir Castle on the north-east, and from Stanford-upon-Soar on the south-west, through Old Dalby and Holwell, to Melton Mowbray and Stapleford Park on the south-east (see Fig. 1). This country is underlain by Mesozoic formations, ranging from the Keuper Marl up to the Lincolnshire Limestone, in regular sequence without any conspicuous unconformity, but deeply covered in places by Glacial drift and later valley-deposits. The Mesozoic strata have a prevalent dip at a very low angle toward south-east, so that successively newer members of the sequence are reached when the ground is traversed in this direction. There are, however, some local

* "Ann. Rep. for 1891" (*Mem. Geol. Surv.*), p. 249 (1892).

undulations and small faults which interfere in minor degree with this sequence.

So far as the "solid" geology is concerned, the original mapping on the one-inch scale required very little modification; and this part of the new work consisted mainly in tracing the boundaries with the closer accuracy and fuller detail that is rendered possible by the use of the six-inch field-maps, and in inserting new boundaries in accordance with the advances in rock-classification since the previous survey. The glacial deposits, however, which form such an important factor in the structure of the district, had not been previously mapped, except in the small part of the new sheet which falls within Sheets 64 and 70 of the Old Series Ordnance Maps.

### TRIAS.

*Keuper Marl.*—The upper part of the Keuper Marl occupies the north-western corner of the new map and extends thence southward along its western margin, preserving the same characters as in the country to the northward described in last year's SUMMARY. The "tea-green marl," however, which forms the uppermost portion of the Keuper series, is much more conspicuous than in its previously-mapped outcrop to the north-eastward, partly from the bolder aspect of the escarpment formed by the overlying series, and partly from an increase in its thickness. It is especially prominent south-west of Keyworth, around the long spurs of the much dissected escarpment, of which it is the chief constituent. Mr. Sherlock and Mr. Smith.

The Keuper country generally in this district shows greater diversity of surface than is usual to this formation, being much broken by the numerous small streams draining westward and northward to the Trent. It is noteworthy that the low flat tract forming Gotham and Bunny Moors occurs on the horizon of gypsiferous marl, like the similar flats south-west of Newark.

### *Rhætic.*

The Rhætic beds cap the above-mentioned escarpment, but are rarely exposed in section. The actual base was seen only in a cutting on the main road at Bunny Hill, while the higher part of the series was best exposed in the canal-cutting at Blue Hill, one mile north-east of Owthorpe. The hard, close-textured, argillaceous limestone, not more than a foot in thickness, which is regarded as the topmost bed of the Rhætic, was formerly dug extensively for road-metal and rough building; but the only sections in which the band is now well exposed are in the canal-cutting just referred to, and in a small pit at Cotgrave Gorse, though it may be readily traced by its abundant fragments in the soil, and is visible in the stream-beds in two or three places. The best section of the Rhætic beds in the district was that exposed in the railway-cutting on the Great Central line, one mile south-west of East

Leake Station, which was described by Mr. C. Fox Strangways in the year 1897,* and is now somewhat obscure. This section lies just beyond the western edge of the map.

## LIAS.

### *Lower Lias.*

The Lower Lias is the predominant formation of the map, occupying over two-thirds of its area. Its outcrop covers the whole of the Vale of Belvoir, and swings round southward, under a thick capping of boulder-clay, into the Wreak Valley, which, east of Hoby, lies entirely within this formation.

ıerlock mith. The lowermost beds (zone of *Psiloceras planorbis*) include many bands of flaggy argillaceous limestone, which are extensively quarried for hydraulic cement near Owthorpe and around Barrow-upon-Soar and Barnston. The outcrop of these beds is nearly three miles wide between Cropwell Bishop and Kinoulton, owing partly to the very low and slightly undulating dip, and partly to the shape of the ground; but it contracts greatly both to the north-eastward and to the south-westward, being, however, much obscured by drift in the latter direction. The valleys of the streams draining the Vale of Belvoir, which are usually shallow and ill-defined, become sharply marked and contracted where they cross these beds.

On the original one-inch map (Sheet 71), the Rhætic was included within the Lower Lias, but has now been separately indicated. For this reason the discrepancy between the old map and the new with respect to the base of the Lias appears to be greater than it actually is. Some further changes in the position of the boundary have, however, been introduced, particularly in the district between Clipston and Wysall.

ɔibson Above the somewhat indefinite upper boundary of the "stone-beds" or *planorbis*-beds, we find a thick series of dark-blue clays with calcareous nodules and impersistent limestone bands, belonging to the zones of *Schlotheimia angulata* and *Coroniceras bucklandi*; but the exposures of this series are everywhere poor, and afforded little new information. A few characteristic fossils of the *bucklandi*-zone were obtained from the material thrown out in excavating a reservoir at the Holwell Iron Works, two miles west of Melton Mowbray; and this was the only place at which an opportunity was found for studying the fauna of these beds. The thickness of the combined zones is estimated to be over 200 feet.

The next zone in the upward succession is that of *Arnioceras semicostatum*, which includes about 120 feet of calcareous clays or shales, with several rock-bands. The important beds of ironstone which occur in this zone in North Lincolnshire are represented only by a band of ferruginous limestone, not exceeding 3 feet in thickness, which has been traced in

* *Geol. Mag.*, dec. iv., vol. iv. pp. 51-53.

the north-eastern part of the map from Barkestone to Harby, but appears then to lose its ferruginous character and is no longer recognisable. In the clays above this band in the same district there are several layers of fossiliferous limestone from 3 to 6 inches in thickness, which form well-defined features, but these also become less conspicuous when traced south-westward, so that their identity is lost. As might indeed be expected, all these thin limestones evidently represent local conditions that prevailed over limited areas during the period, now in one place and now in another.

At or near the top of the *semicostatum*-beds there occurs a more persistent sandy belt that has not previously received particular notice; and we were able to trace this belt fairly continuously across the Lower Lias plain, up to its disappearance beneath the plateau of glacial drift. It is most conspicuous toward the south-western end of the Vale of Belvoir, its outcrop capping the sharp rise on which stand the villages of Long Clawson, Nether Broughton, and Upper Broughton. At these places the bed is over 10 feet thick, consisting of more or less sandy shale, with irregular lenticles of hard sandy limestone containing many lamellibranchs and a few brachiopods. Its thickness diminishes to a few inches toward the north-east, but it maintains its sandy character up to the edge of the map in this direction. West of Upper Broughton, though hidden under boulder-clay, it is probably continued round the long spur of Middle Lias, as it is seen again on the south side of the spur in the railway-cutting 850 yards N.W. of Holwell Iron Works. This band affords the water supply of the villages along its outcrop, and it has been dug for brick-making at Upper Broughton. Mr. Lam lugh, Mr. Gibs and Mr. Smith

The clays of the upper portion of the Lower Lias above the sandy belt are about 300 feet thick, representing the zones of *Oxynoticeras oxynotus*, *Uptonia jamesoni*, and *Amblycoceras capricornus*. Along their northern outcrop below the Middle Lias escarpment they are very poorly exposed, and except that they generally weather into a pale-blue clay-subsoil, deficient in lime, and stained rustily with iron indicating the presence of pyrites, there is little information to be gathered respecting them. They were, however, pierced by the shafts of the tunnel between Old Dalby and Grimston, and some of the characteristic fossils of the *jamesoni*-zone may still be collected from the spoil-heaps.

In the south-eastern corner of the map, around Stapleford Park the *jamesoni* and *capricornus*-zones were identified, the best exposures being afforded by the railway-cuttings east of Saxby Station. Mr. Wedd

### *Middle Lias.*

The Middle Lias outcrop enters the map at the north-eastern corner near Belvoir, where it is deeply indented by the valley of the River Devon. It then runs south-westward in a bold and picturesque escarpment to Eastwell, and throws out a long Mr. Gibs Mr. Wedd and Mr. Lamplugh

narrow spur as far westward as the Midland Railway line at Old Dalby. On the south side of this spur the boundary doubles back, and runs up to the eastern edge of the map again a little south of Stonesby, being here, however, completely buried under drift.

The lower portion of the Middle Lias (zone of *Amaltheus margaritatus*) consists of 100 to 120 feet of bluish clay, with occasional nodular bands, resembling in lithological character the underlying clays of the Lower Lias. Within the present district this portion is very poorly exposed, and the line at its base has been drawn on the strength of palæontological evidence obtained outside the district. At present the only exposures of these clays are in some obscure stream-sections at the head of the River Devon, and in a brickyard about a mile north-east of Long Clawson Station.

The Marlstone series, or upper part of the Middle Lias, though not exceeding 40 feet in thickness, is both economically and physically the most important feature of the map. It consists, in upward succession, of thin-bedded sandstone and sandy shale, sandy limestone, and ferruginous limestone and ironstone. These beds form the crest of the great escarpment above-mentioned, extending back from it south-eastward in a gentle dip-slope; and these conditions, like those in the Northampton Sands pointed out by Prof. J. W. Judd in a former memoir on the district,* have favoured the weathering and alteration of the originally calcareous rock into a relatively rich iron-ore, and this iron-ore occupies the surface over a large area, where it is easily won in shallow open-cast workings. Therefore, along the whole outcrop, from Belvoir Terrace to Wartnaby, the ironstone has been extensively worked, and the industry is still in full activity, though the amount of accessible ore now remaining is much less than that which has been removed. The chief workings at present in operation are those of the Staveley Iron and Coal Company, at Stathern and Eastwell; of the Stanton Iron and Coal Company, near Woolsthorpe, Harston, Holwell, Ab Kettleby, and Wartnaby; the Bennerley Iron and Coal Company, near Holwell; and the Holwell Iron Company, near Eastwell and Holwell. The method of working is in all cases the same; the soil and subsoil, with other overburden, is removed in a long narrow strip, and used as infilling immediately behind the advancing trench from which the iron-ore is excavated, so that the cultivation of the land to the rear of the trench is speedily resumed. The thickness of merchantable ore varies from 3 to 14 feet, according to the position of the workings; and it is underlain by a hard sandy limestone, often decalcified into a soft sandstone, which is known to the workmen as the "sand-rock."

The best section of these lower sandy beds is that exposed in a cutting on the mineral railway half a mile north of Holwell,

* "Geology of Rutland" (*Mem. Geol. Surv.*) (1875), chap. vi.

where they are exposed to a depth of 18 feet, and pass toward the base into sandy shale, with thin intercalations of clay. About 12 feet above their base in this section, there is a thin seam of pebbly aspect, containing many fossils, mostly fragmentary and worn, along with small rolled concretions, perhaps originally phosphatic. A similar band was observed near Eastwell, and on Belvoir Terrace Hills and other places, and it probably marks, throughout the district, an horizon of slight contemporaneous erosion.

Although the ironstone phase of the Marlstone always occurs in the uppermost part of the series, it appears to extend downward to a variable depth in the rock, so that its base does not denote a definite horizon, but varies with the locality.

The spur of Marlstone extends farther westward than was shown on the old map, as there is a slight exposure of ferruginous sandstone near the top of the steep valley-side in Old Dalby Wood, a furlong west of the boundary previously shown. A thick capping of boulder-clay, however, intervenes between this exposure and the main outcrop to the eastward. Mr. Smith

Several small faults have been traced in the Marlstone, and though unimportant geologically, these are of considerable economic consequence in diminishing or increasing the available iron-ore.

The country to the southward of the Marlstone spur is occupied by a great sheet of boulder-clay, which completely masks the "solid" geology, the underlying strata being seen only in very obscure exposures in the deep valleys and in a few railway cuttings.

*Upper Lias.*

Small patches of the Upper Lias clay, occupying depressions in the Marlstone, are occasionally revealed in the ironstone workings between Holwell and Wartnaby. Striking examples occur in the deep working at Stonepit Houses half a mile N.W. of Wartnaby Church, where the surface of the ironstone is broken into curiously irregular step-like blocks, mainly due to slight vertical displacements along the joints in the vicinity of a small fault. One of the narrow troughs thus formed has been deepened by weathering into a long "gull" or fissure into which a strip of pale-blue Upper Lias clay has been bent down, and thus preserved from erosion. This clay contains the impressions of ammonites of the *serpentinus*-group in abundance, along with belemnites and a few other fossils. Mr. Lau lugh.

These lowest beds of the Upper Lias are, however, best exposed in the ironstone workings east of Holwell, and at White Lodge, near Goadby Marwood. At these places the workings have followed the Middle Lias ironstone under the margin of the overlying Upper Lias clays, which are stripped off to a depth of about 15 feet. The surface of the ironstone-rock in these sections exhibits the same curious step-like structure as at Wartnaby, and these small dislocations die out upward in the Upper Lias clays. Some large nodules Mr. Wedd

of fine-grained brownish-limestone (containing scattered scales and other fragments of fish), that are embedded in the surface of the ironstone-rock, probably belong to the "fish and insect beds" of the Upper Lias, which attain much fuller development in the country to the southward.

The middle part of the Upper Lias is at present nowhere exposed in section, and the highest beds are seen only at the Stonesby Brickyard, where they have been dug to a depth of 17 feet, and consist of blue, somewhat shaly clays, almost unfossiliferous, with a band of large septarian concretions, and seams of pyritous nodules which produce large crystals of selenite on decomposition.

Some alterations in the previously-adopted boundary of the Upper Lias have been found requisite in the neighbourhood of Scalford, as the fresh evidence does not sustain the view that there is a faulted boundary in this quarter.

### LOWER OOLITES.

#### *Northampton Sands and Ironstone.*

This series, with the overlying Lower Estuarine Beds, occupies a small area in the eastern part of the map, around Stonesby, Waltham, and Croxton Park. It is no longer worked for ironstone anywhere in the district, and as the old workings are now grassed over, very little new information could be obtained respecting these beds. The ironstone is at present best seen at the Stonesby brick-pit, where the section shows a few feet of hard ferruginous sandstone, brought down against Upper Lias clay by a small fault. The sandstone is poor in fossils, and shows the cellular structure described by Prof. Judd as being due to the segregation of iron.

The outlier of ferruginous sandstone of this series at Goadby Marwood is probably of greater extent than was indicated on the old map. Its correlation with the Northampton series, originally regarded as somewhat doubtful, has been satisfactorily confirmed.

The outcrop of the Lower Estuarine beds is usually indicated by a slight depression of the surface; but exposures in this area are confined to the small ponds, which show whitish and pale-blue laminated sandy clay. On the north side of Stonesby the presence of a band of soft yellow sand at the top of the group, as mentioned in the previous memoir, is indicated by the material thrown out by rabbits.

#### *Lincolnshire Limestone.*

This division occurs only in a large outlier north-east of Waltham with smaller faulted masses adjacent to it. The portion exposed in this district consists of about 20 feet of pale limestone beds, predominantly oolitic but varying in this particular, with occasional sandy bands and a thin seam of clay in the lower part. An excellent section is revealed in the

large quarries east of Waltham, indicated on the old map; but except at this place there are practically no exposures. Considering the character of the rock, it is remarkable that the surface feature along its outcrop should be inconspicuous and ill-defined.

## PLEISTOCENE AND RECENT.

### *Glacial Deposits.*

Mr. Wedd, Mr. Smith, Mr. Gibson and Mr. Lamplugh.

The drifts of the Melton Mowbray map are especially interesting, inasmuch as the area shows the northern termination in this part of the Midlands of the great mass of Chalky Boulder-clay which spreads so extensively to the southward and eastward, while the country to the northward (as described in last year's SUMMARY, p. 11), is comparatively driftless. The facts brought out in the mapping of these sharply-divided areas show that the absence of drift affords no proof that the now-driftless area escaped glaciation.

The great sheet of Chalky Boulder-clay, levelling up all the minor inequalities of the old surface and attaining in places a thickness of at least 150 feet, covers the country within the map on the south and south-east as a well-marked plateau, much dissected by recent streams. Where not removed by the post-glacial denudation, it overlies all the Lower Lias south of the Marlstone spur, but thins out or is broken up into irregular tongues along the Marlstone outcrop. Where the Marlstone spur terminates westward, the plateau of boulder clay sweeps northward round the end of the ridge and crosses the Lower Lias in an elevated belt, gradually narrowing and becoming much dissected, but traceable up to the northern margin of the map near Clipston.

In this belt, however, though the continuity of the plateau is maintained, the dark-blue boulder-clay loses its chalky character and merges gradually into a red drift of different aspect, derived mainly from the Triassic rocks. There is every indication that these differently-constituted boulder-clays were accumulated simultaneously, though in the Wreak Valley and elsewhere along the south-western margin of the map, as described by Mr. C. Fox-Strangways, a red boulder-clay of local origin often occurs at the base of the drifts, and is usually separated from the overlying Chalky Boulder-clay by stratified drift. In a brick-yard on the northern side of Melton Mowbray, the lower part of the section is largely composed of a leaden-grey clay with few stones, derived almost entirely from the Lias, much contorted, and confusedly mixed with a red clay obscurely laminated, the whole being overlain by Chalky Boulder-clay of the normal type.

South of the high Marlstone spur, the effect of the boulder-clay is partly to fill up the Lower Lias depression, so that the country falls away very gradually southward from the steep northerly escarpment of the Middle Lias, and no pronounced feature is developed along the southern edge of the Marlstone. Between Eastwell and Stat-

hern there appears to be a deep gap in the escarpment which is entirely filled with drift. The same conditions recur a little to the westward of Long Clawson Station; and it is curious to find that in these cases the drift ends off along with the "solid" escarpment, and does not encroach upon the low country beyond it.

Still more striking is the position of the boulder-clay in the elevated belt, which, as above-mentioned, runs northward from the end of the Marlstone spur at Old Dalby. Between this place and Owthorpe, the plateau occupied by the boulder-clay breaks off suddenly eastward in a steep feature, of which the crest is usually at least 100 feet above the base. The feature appears to be an actual escarpment of the boulder-clay, for its direction is oblique to the strike of the underlying Lower Lias.

In the great triangular stretch of low ground, six miles across the base, between this feature and the Marlstone escarpment, the Lower Lias is everywhere close to the surface, the only indication of drift being a sprinkling of transported stones or an occasional "pocket" of gravel 3 or 4 feet in depth. The ill-defined "Vale of Belvoir" forms the northern part of this almost driftless plain, but it will be convenient to extend the topographical term to the whole tract.

Although this low ground has yielded nothing that could be definitely recognized as boulder-clay, there is clear evidence that it must have participated in the glaciation equally with the surrounding country, in spite of the present abrupt termination of the boulder-clay at the edge of the plateau.

Lamp- In the ironstone-working close to the crest of the Marlstone escarpment at Stonepit Houses, half a mile N.W. of Wartnaby, at 500 feet above O.D., the ore has been followed under the edge of the boulder-clay, which increases rapidly westward, from 3 or 4 feet, to 15 feet in thickness. Beneath this boulder-clay the protruding bosses on the uneven surface of ironstone mentioned on a previous page (p. 19) are all distinctly glaciated, and, in several cases, showed ice-scratchings that demonstrated a movement of the ice from N. 10° W. toward S. 10° E., *i.e.*, a movement *from* the present low ground and *across* the high escarpment at a right angle. The boulder-clay in this section is made up chiefly of Liassic material, with a few far-travelled boulders of Carboniferous rocks (the Carboniferous Limestone boulders being magnificently polished and striated). There is a notable rarity of chalk or flint in the section, especially in the lower part, where, indeed, only a single Cretaceous fragment (of Red Chalk, containing the characteristic *Belemnites minimus*) was found. Adjacent sections, however, at nearly the same level, and in the same sheet of boulder-clay, show an abundance of material derived from the chalk and from the Lincolnshire Limestone, and there is no division traceable between the chalky and chalkless drift of the plateau.

From this and other evidence of similar character it is no longer possible to regard the Vale of Belvoir as an unglaciated area; but whether it was once covered by a sheet of drift which has been subsequently removed by erosion, or whether it is a tract upon which little or no drift was ever deposited, is still an open question. That the boulder-clay has undergone very extensive denudation is shown not only by its truncation along the escarpment, but also by its deep trenching by all the streams. These have developed wide valleys that are often cut completely through the drift, and to some depth into the Lias also. But it is difficult to imagine under what conditions the drift could be so systematically removed from the whole of the Vale of Belvoir, and yet remain in its present quantity on the plateau. Probably, therefore, the Vale is an area where, from the original shape of the ground and its relation to the ice-movement, there was very little accumulation of drift during the glaciation. The vast amount of Liassic material that has gone to the making of the Midland boulder-clays shows that there must have been extensive tracts of Lias which were being stripped during the glaciation. On the other hand, the thickness of the drift overlying many wide areas of the Lias must have protected these particular areas from glacial erosion—at least during the later stages of the glaciation, and probably at the expense of the tracts that were being stripped.

During the course of the glaciation in this, as in most glaciated areas, there appear to have been changes in the direction of the major ice-flow, and the striæ at Wartnaby indicate only one—probably an early—phase of the movement. Thus, at the only other place within the map where glacial striæ have been observed (viz., in the Stanton Tunnel on the Midland Railway, between the stations of Plumtree and Widmerpool, in a section examined a quarter of a century ago by the present Director of the Survey, Dr. Teall), the ice-scratchings on a surface of Lias limestone were approximately N.E.—S.W.; and this direction more nearly agrees with the general travel of the transported material.

In mapping the boulder-clay it is found that certain belts are distinguishable by the predominance of débris of a particular kind; from which, however, must be excluded the Carboniferous boulders, for though relatively few, these are ubiquitous, evenly distributed, and never clustered.

South of the Marlstone spur, chalk and flint are widely distributed and locally abundant, but still tend to predominate in distinct areas. The Lower Oolite material, being nearer its source, shows a stronger tendency to local segregation, and preponderates in a narrow belt extending, and also expanding, south-westward from the Lincolnshire Limestone outcrop of Waltham to the neighbourhood of Welby and Sysonby, while on the north-west side of this belt, in the neighbourhood of Chadwell and Scalford, the boulder-clay is extremely chalky. Mr. Wedd

The same predominant direction of transport is indicated Mr. S

by the upland drift west of the Vale of Belvoir. In the northern part of this tract the boulder-clay has a reddish matrix, and contains a large admixture of Keuper Marl and Rhætic shales; east of Widmerpool its matrix is dull-blue, and chalk is abundant; west of Old Dalby, along with flints, boulders of the ferruginous Marlstone and of oolitic limestone are present in large numbers; while pebbles from the Bunter, occur throughout. The distribution of the material appears to indicate, in the north of the area, an ice-movement from some degrees N. of N.E. swinging to some degrees E. of N.E. in the southern part.

Sher- With the exception of a few isolated streaks and pockets of loam, sand and gravel, there is a remarkable absence of stratified drift on the boulder-clay plateau until we approach its western margin, where such deposits begin to assume importance. Along this margin, from Plumtree to Stanford, strips of sand and gravel emerge at frequent intervals from beneath the boulder-clay, and occasionally also overlie it or apparently replace it altogether, while in the otherwise drift-less country to the north-westward, gravelly deposits frequently cap the highest ground, *e.g.*, at Wilford Hill, Bradmore, and East Leake Hills, and a thin gravelly wash is spread very generally over the lower ground, greatly modifying the character of the soil over the Keuper Marl, and causing much difficulty in the mapping. Some of these gravels are certainly of glacial age and origin, while others appear to mark the rapid erosion of the country during the melting of the ice, and afford a link between the glacial deposits proper and the oldest flood gravels of the existing valleys, this succession being best displayed in the basin of the Fairham Brook, between Bunny and Widmerpool.

Wedd. The stratified drift intercalated with the boulder-clays of the Wreak Valley has already been referred to, and similar deposits, becoming however of coarser texture eastward, are visible at intervals along the northern slopes of the continuation of this valley (the river being here named the Eye) east of Melton Mowbray.

Gibson. On the outer slope of the Marlstone escarpment south of Belvoir Castle, and in the deep valleys of the Devon and its little tributaries which lie just within this part of the escarpment, there is a considerable development of stratified sand occurring under conditions difficult of explanation. On the outer slope, this sand is found in isolated patches at about 300 feet above O.D., but in the valley of the Devon it forms a wide strip rising gradually from about 200 feet to 400 feet above sea-level, and sends off branches to form terraces high up on the sides of the narrow side-valleys, often masked by the rubbly downwash of the steep hillsides.

The sand, seen to a thickness of over 15 feet, is clean and evenly graded, containing only here and there a quartzite pebble or a chip of flint. It cannot have been derived from the local rocks, but may represent the washings from the

Bunter. Its relation to the Chalky Boulder-clay is not clear, as the two deposits do not occur together; but it is difficult to believe that the smaller of the valleys within which it lies can have been in existence before the deposition of the boulder-clay.

The most probable explanation is that the sands have accumulated in a marginal sheet of water at the edge of the ice during the melting of the glacier which occupied the Vale of Belvoir.

*Post-Glacial.*

Mr. Wedd, Mr. Shelock, and M Smith.

The flats bordering small streams on the Lower Lias clays and on the Keuper Marl are often unusually wide, with ill-defined outer margins, but it is doubtful whether these flats have been wholly planed down by the streams, as would at first sight be supposed. In many cases it is more probable that they represent the general lowering of the surface occupied by exceptionally "weak" strata, under ordinary atmospheric weathering, down to the lowest level at which degradation is possible. In such instances, the original valley-floor is more or less protected by its covering of alluvium, until the bounding slopes of "weak" material are lowered to its own level. On the low ground it was frequently observed that while the stream-flat was widely extended, the actual deposits of alluvium were confined to a comparatively narrow strip along the course of the stream, as would happen under the above conditions.

Mr. Shelock.

The largest tract of alluvium mapped during the year occupies a flat of about 4 sq. miles, known as Gotham Moor and Bunny Moor, along the course of the Fairham Brook. This flat has a peaty surface overlying muddy and sandy alluvium of no great thickness, resting on the gypsiferous portion of the Keuper Marl. Similar though less extensive flats recur frequently along the strike of these beds between this place and Newark, as mentioned in last year's SUMMARY (p. 13.).

Mr. Wedd.

An interesting section of ancient alluvium is exposed in Barnes's brickyard on the northern outskirts of Melton Mowbray, at the confluence of a side-valley with the broad valley of the Eye. At a depth of about 9 feet, beneath loamy brick-earth, there occurs a tough blue clay, of which the sandy base contains boles and roots of trees, with bark and hazel-nuts. This bed rests upon a thin irregular band of coarse gravel, containing many flints derived from the Chalky Boulder-clay; and in this gravel are occasionally found well-preserved mammalian bones. These remains include a human cranium, the skull of a horse, and bones and antlers of red deer. The gravel rests upon red and grey clay, equivalent to the lower boulder-clay of the adjacent pit previously mentioned (p. 21), the Chalky Boulder-clay having been removed by erosion before the gravel was deposited.

ECONOMIC GEOLOGY.

*Ironstone.*—The most important mineral product of the

district is the Middle Lias Ironstone. The workings for this ore have been briefly described in a preceding paragraph (p. 18), and a more detailed account will be given in the forthcoming memoir. The ironstone of the Northampton Sands is no longer worked in this area (see p. 20); and the beds corresponding to the Lower Lias iron-ore of North Lincolnshire have almost entirely lost their ferruginous character before entering the present map (pp. 16, 17).

*Hydraulic Cement.*—The argillaceous limestones at the base of the Lower Lias are famous for the high quality of the cement made from them. The important cement works of Barrow-upon-Soar and Barnston lie respectively at the south-west and north-east margins of the present map, and the stone is also extensively raised at Owthorpe.

*Gypsum.*—Gypsum works have been established at Cropwell Bishop, and at Hotchley Hill near East Leake, the raw material being obtained from the upper portion of the Keuper Marls. The most productive works for this mineral lie, however, a little beyond the northern and westward boundaries of the map.

*Coal.*—Deep borings have been made in search of coal beneath the newer rocks at Ruddington and Owthorpe, in the north-western part of the map, with results that are very important in showing the south-eastern extension of the concealed portion of the Nottingham Coalfield. These results were closely studied by the late James Shipman, F.G.S., and the borings have been described by Lieut. G. E. Coke, F.G.S.*

*Building Stone.*—The flaggy limestone-bands of the Lower Lias, the Marlstone of the Middle Lias, and the Lincolnshire Limestone have all been used locally for building, but are not sufficiently good in this district for export; and even for local purposes, except rough-walling, a better stone is now usually imported.

*Bricks.*—The local demand is largely supplied from brick-yards working the boulder-clay or Lias clays; but the industry is relatively unimportant, and most of the smaller yards are at present closed.

*Road-metal.*—Charnwood rocks and furnace-slag are the principal materials used for mending roads throughout the district. The hard splintery limestone-band at the top of the Rhætic, and the Lincolnshire Limestone, were formerly much sought for this purpose, but their use is now very restricted.

*Agriculture.*—The district is essentially agricultural and largely pastoral, the heavy clay-lands of the Lower Lias and boulder-clay being mainly under grass. To this prevalence of grass-land is due the celebrity of Melton Mowbray as a centre for fox-hunting, which, if not exactly an industry, is, at any rate, a source of profit to the inhabitants. On the lighter soils of the Marlstone, the Lincolnshire Limestone, and the gravelly

* *Trans. Fed. Inst. Min. Engineers*, vol. xi. (1895-6), pp. 334-344.

tracts overlying the Keuper Marl, the proportion of land under the plough is much greater than in the clayey tracts.

For the purpose of testing the relationship between the geological boundaries and the character of the soils, an investigation was undertaken in a portion of the district, while the geological field work was in progress, by Mr. A. D. Hall, of the Rothamsted Experimental Station, and Prof T. H. Middleton, now of the Board of Agriculture, and results of interest may be expected when the work is finished.

## II.—Southern District—Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Dr. John S. Flett, M.A., Petrographer.
Mr. W. A. E. Ussher, Mr. George Barrow, Mr. J. B. Hill, Mr. D. A. MacAlister, Mr. H. Dewey — Geologists.

Mr. Reid. During 1906 field-work was carried on in two areas. In the Lizard (359) Dr. Flett and Mr. Hill continued the mapping, Dr. Flett taking the Serpentine and associated rocks, and Mr. Hill taking the part to the north of the Serpentine. In the other area, extending from Trevose Head to Bodmin Moor, and from St. Breward and St. Kew to St. Columb Major (335, 336, 337, 347) the rest of the officers continued the work of the previous season. Messrs. Barrow and MacAlister completed the St. Austell map (347). Mr. Reid finished the mapping in the Trevose Head sheet (335). Messrs. Reid and Dewey examined the lower part of the Camel Valley, and Mr. Barrow continued the work around Bodmin and Bodmin Moor. Thus the southern half of the Camelford map (336), is finished, and work is also proceeding in the Tavistock sheet (337).

As Sheets 335, 336, 359 are not yet completed, and the palæontological and petrological material obtained during the past season is only partly worked out, it will be best not to anticipate results in these unfinished areas, especially as various points are still uncertain.

### Serpentine and associated rocks.

#### *The Southern Lizard District.*

Dr. Flett. The revision of the southern part of the Lizard sheet (359), including the area occupied by the hornblende schists, serpentine and gabbro, has been begun by Dr. Flett, who spent three months engaged in this work during the summer of 1906. He reports that, as the various types of rock which occur there are very distinct, and the surface formations are thin, the boundaries laid down on the current edition of the map, which is founded on that executed by Sir Henry De la Beche, will require little modification so far as regards the distribution of the serpentine and the hornblende schists. It has been found, however, that the area occupied by the rocks of the "granulitic group" is much larger than has hitherto been suspected. They include hornblendic and micaceous schists and gneisses, with granulitic aplite and granite. A large part of Goonhilly

Down, in the very heart of the serpentine, consists of granite or aplite, usually with very little foliation; similar rocks cover much of the ground around Erissey and appear also in many of the stream-sections around Poltesco. They floor the Cadgwith Valley for a distance of nearly half a mile from its mouth. Little is seen of them on the flat-topped plateau which forms most of the Lizard country, but this is merely because, as compared with the serpentine, which is one of the most resistant of all rocks to atmospheric decay, they crumble down readily and are covered with soil and vegetation. Their principal development lies to the east of the main road from Helston to the Lizard. West of this, they appear in some strength, near Clahar Garden, and are seen in a number of isolated spots here and there, especially in the coast sections. Their relations to the serpentine often indicate very clearly that they are intrusive into it, as was proved by Dr. Teall and Mr. Howard Fox,* in 1893.

The serpentine, when its relations to the hornblende schists and other rocks which surround it are mapped out, is found to be a large boss or stock of intrusive character. By individual sections this can hardly be established, as the junctions of the rocks of these two series are commonly faulted, but when the amount of disturbance is unusually small (as at Ugo Dour and Parc Bean), the facts are at least in accordance with this hypothesis, if they do not quite demonstrate it. But the manner in which the serpentine creeps across the outcrops of the schist and the sharply-defined nature of the boundaries between them, together with the presence in the schist of occasional inliers of fine-grained serpentine (which may reasonably be regarded as dykes or sills) is explicable only on this theory. There are also reasons to suppose that contact alteration, in a more or less intense degree, has affected a considerable part of the area which surrounds the boss.

The hornblendic schists contain intercalations of mica schist at Porthallow, Penolver, and elsewhere. At Old Lizard Head and Polpeor, a group of sediments, including quartzites, felspathic granulites, grey and pinkish mica-schists (which may be garnetiferous) and silky, fine, hornblendic green schists, is well exposed in the coast sections. The fine green schists may well be lavas and ash-beds, while the coarser and more crystalline hornblende schists are possibly of intrusive origin. Often the bedding of these rocks is well preserved, though they are much crumpled. At Venton Hill Point the mica schists contain andalusite, and at more than one place in this district they present characters which indicate that they have suffered contact alteration.

There is also a set of later dykes, sometimes ophitic, often porphyritic, and more or less sheared, which intersect the mica schists, hornblende schists and serpentine, and also, it is believed, the granulitic series.

* *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 199.

The succession, consequently, is as follows:—

5. Later dykes and sills.
4. Granulitic series.
3. Gabbro.
2. Serpentine.
$1^b$. Lizard, Predannack and Mullion hornblende schists.
$1^a$. Mica schists, quartzites, &c., of Old Lizard Head and Polpeor.

As more than half of the district has not yet been re-surveyed, there are many problems which must be left for further investigation. The northern boundary, so far as Dr. Flett has followed it, is a sharply-defined and considerable fault. No new or large area of the gabbro has been met with in the district examined during the summer. The serpentine is partly of a fine well-foliated variety, but elsewhere coarse-grained and often not greatly sheared. The relations of these different varieties of serpentine to one another, and the meaning and history of the foliation in them and in the gabbro and granulitic groups, is the main crux of the Lizard problem, and it is hoped that another season's work will throw some light on these obscure questions.

## PALÆOZOIC ROCKS.

### *The Northern Lizard District.*

J. B. Mr. Hill has been engaged on the Lizard sheet (359), and has completed the mapping of the area lying to the north of the Lizard group.

The killas deposits embrace both Lower and Upper Palæozoic —the former sequence consisting of the Mylor, Falmouth, Portscatho, and Veryan groups, and the latter of the Manaccan series (Lower Devonian). The newer Palæozoic Rocks are divided from the older by an important unconformity.

In the Lower Palæozoic, fossils are rare and, for the most part, of little stratigraphical value. The Veryan series, however, has yielded Ordovician fossils, and it is probable that this division is of Arenig Age. The relations of this sequence to the overlying Devonian suggests that the Falmouth and Mylor divisions were not exposed to Devonian denudation, and that the sequence is descending from the Veryan to the Mylor group. The lower deposits, therefore, may represent the base of the Ordovician or the top of the Cambrian.

The four divisions of the Lower Palæozoics form broad bands crossing the map from E.N.E. to W.S.W., the Mylor series lying to the north, followed successively by the Falmouth, Portscatho and Veryan groups towards the south. The Lower Devonian, represented by the Manaccan series, is far more restricted in its distribution, and consists of outliers extending from Nare Point on the east to Gunwalloe on the west.

The igneous rocks within the killas area embrace intrusive

and contemporaneous—the former are represented by granite, elvan, mica trap, greenstone, dolerite and hornblende schist; and the other by pillow lavas of the spilite group.

*Lithological Characters of the Palæozoic Divisions.*—The Mylor, Falmouth, and Portscatho groups consist of sandy and argillaceous slate in which chert is sometimes represented. The Veryan group, which forms the upper member of the Lower Palæozoic sequence, consists of argillaceous and sandy killas, together with quartzite, limestone, and chert. The volcanic rocks are represented by pillow lava and ash beds. The cherts have reached a greater development than in the underlying divisions. The limestone forms very small bands, rarely large enough to be mapped, but calcareous material frequently permeates the sandy sediments. Moreover, the presence of quartzite, among which felspathic types play an important rôle, imparts a special character to this division. There are also quartzitic bands representing transitional types between quartzite and sandstone. The sandy beds of this division are, moreover, rich in felspar. The lithology is further diversified by the presence of crystalline schists, together with transitional types between the latter and normal killas.

The Manaccan series (Lower Devonian) is represented by conglomerate, sandstone and clay slate. The conglomerate is largely composed of detritus from the Portscatho and Veryan groups, while fragments of granitic and metamorphic rocks are also incorporated.

*Deformation of the Palæozoic Divisions.*—As described in former reports, the killas of West Cornwall has not only been sharply plicated, and cleaved, and closely faulted, but crush breccias have also been developed on an extensive scale. These crustal movements belong to two epochs, the earlier of which is of pre-Devonian age, and therefore only affected the Lower Palæozoics, while the later has involved the entire Palæozoic sequence of Cornwall up to the Culm-measures. Of these crustal disturbances, it is the latter that has imparted the dominant structure to the killas of the South-West of England. Notwithstanding, however, that the earlier deformation has been largely masked by the post-Carboniferous stresses, it can be shewn that they resulted in deformational and metamorphic processes of an advanced type. In the area south of the Helford River, crush breccias are developed on an enormous scale within the Veryan series, some of which are only distinguished with difficulty from the Devonian conglomerate. These breccias not only affect the sandy and argillaceous beds, but have involved the destruction of such massive rocks as quartzite, pillow lava and hornblende schist. But, besides the formation of extensive crush breccias, those earlier stresses have evolved mica schists in the Ordovician rocks, and both these metamorphic products are represented in the Devonian conglomerate.

*The Veryan Group.*—As this group presents features of exceptional interest, its salient features will be described. It

lies between the Portscatho group on the north and the Lizard group on the south, and is in part overlain unconformably by the Lower Devonian.

Ignoring subordinate members of the group, the sequence from north to south is as follows:—

1. Sandy and argillaceous killas.
2. Quartzite.
3. Sandy and argillaceous killas.
4. Pillow lava and ash beds.
5. Sandy and argillaceous killas, with increase of metamorphism at its boundary with the Lizard group.

Besides these members there occurs within Group 1, a belt of hornblende schist extending, as lenticles, from St. Martin's Green to Tregithey on the south side of Gillan Creek, and apparently prolonged beneath the surface still further east to Penare, but whether it again actually emerges is uncertain. The Veryan killas associated with the hornblende schist has been knotted and converted into phyllites and mica schists, some of which are as advanced in metamorphism as the mica schists of Porthallow. Subsequent to the intrusion of this rock, now in the condition of hornblende schist, the crush conglomerates were evolved, under which the hornblende schists, quartzites and pillow lavas have largely broken down into breccias. The deformation of the pillow lavas, however, has stopped short at this process, and their original igneous structures are exceptionally well preserved. It is evident that the pillow lavas experienced the stresses long after their depositions; the hornblende schist, however, was intruded into the Veryan series at a later period, and probably during the stress epoch itself, so that its foliation may have been set up before final consolidation, and the associated killas being in a heated condition was partially converted into phyllites and mica schist. The Manaccan intrusion, although apparently of the same character as certain rocks in the Lizard group, does not represent the dominant type of hornblende schist of that group.

The boundary between the Lizard group (hornblende schist, serpentine, &c.) and the Veryan group is sometimes faulted. The margin is thus defined between Polurrian and Bochym Lodge, and the killas is, in this case, quite unaltered up to the fault, on the south side of which is hornblende schist. From Bochym to Trethewey no trace of a marginal fault can be detected, the boundary forms a sinuous and irregular course, and the marginal phenomena are markedly different from those of the faulted junction just described. Instead of the hornblende schist being adjacent to normal killas, it is separated from the latter by a narrow belt of phyllites, mica schist and garnetiferous granulite, the latter, where it occurs, forming the inner zone next to the hornblende schist, and the evidence suggests that the phenomena of the Manaccan hornblende schist already described are here reproduced.

Eastward from Tregidden, the marginal killas is represented for some distance by unaltered Devonian sediments that have overlapped on to the Lizard group, while still further east the Veryan series, and possibly the Portscatho beds, are represented along the margin. At Porthallow a fault divides killas on the north from schists on the south.

## DARTMOOR GRANITE AND THE METAMORPHIC AUREOLE.

### *Ivybridge District.*

Before preparing a description of the Geology of Sheet 349 to accompany a colour-printed edition of that map, it was deemed advisable to re-examine, in the light of later experience, the area on the borders of the granite; because the rocks within the aureole of contact metamorphism could not be satisfactorily made out when the hand-coloured edition of that sheet was prepared. For three reasons it was then thought that Culm-measure rocks occurred within the aureole near South Brent, Ivybridge, and Cornwood. Firstly, the presence of chiastolite in dense dark rocks, then only recognized in the Culm. Secondly, the local presence of sandy or silty materials, which might be expected to occur in the Culm. Thirdly, there were numerous outcrops of banded hornstone of a type locally presented by the Lower Culm rocks of Coddon Hill, near Barnstaple. Mr. Ussher.

Subsequent work on the granite aureoles of Dartmoor, near Dousland and Walkhampton; of Bodmin Moor, near St. Neot; and of the St. Austell mass, near Lostwithiel, revealed the fact that by selective metamorphism silicco-calcareous rocks, and very fine slates of Upper, Middle, and Lower Devonian age may be converted into hornstones.

Applying the experience thus acquired to the aureole in Sheet 349, the hornstones were found to pass into unaltered Middle Devonian sediments near South Brent, Ivybridge, and Cornwood (Fardel Mill).

Volcanic rocks, presumably in the upper part of the Middle Devonian, strike directly into the aureole north of South Brent at a point where diabase hornfels, originally lava, comes on. This rock forms the dip slope of Brent Hill and rests on fine dark tuffs.

Where igneous rocks occur within the aureole it is impossible to separate the tuffs and harder diabases, except in the case of a mass at Cornwood Church, where a new road-cutting visited in 1906 showed a good exposure of the former, and of a band 5 feet thick in the Erme, at Ivybridge Paper Mills, which Mr. Barrow, who assisted Mr. Ussher with his experience, pronounced to have been a tuff.

Intrusive masses occur in contact with the granite near Dinnaton (N.W. of Ivybridge), and at the head of Wrangaton Bottom, where Mr. Barrow detected a trace of ophitic struc-

ture in the slide. Hornstones, consisting of biotite hornfels, banded and patched with pale-greenish porcellanized material or *vice versâ*, constitute the chief part of the altered rocks between Brent and Ivybridge. The hornstones pass out eastward in siliceo-calcareous bands or masses associated with the slates (Middle Devonian) at Brent Mill and in the Wrangaton railway cuttings, and then cease to be distinguishable. Westward, they can be traced to the mill near Fardel, south of Cornwood Station, but in the district round Cornwood their presence has only been detected in small patches at Hounâle and near Slade Hall, and in a very impersistent manner between Sparkford and Hemerdon Ball. North and west of Brent Hill the surface evidence is so obscure that the persistence of the igneous rocks and of the hornstones cannot be proved.

The chiastolite rocks consist of dark-coloured dense sediment and of whitish rock, probably of a more silty character; they occur on the margin of the granite on the Down north of Ivybridge, and from thence at intervals to Gidley Bridge, north of South Brent. Between Gidley Bridge, Zempston, and Nurston, in the district north of Brent Hill, grits occur in or on the borders of the contact zone.

The result of the re-investigation is to sweep all the area within the aureole distinguished as Culm on the published map into Devonian, although as regards the chiastolite rocks and grits above referred to, no proof has yet been obtained that they may not be infolds of Culm rocks.

## LOWER DEVONIAN.

id. The Lower Devonian area between St. Columb Major and Lanivet has now been completed, Mr. Barrow mapping the northern part and Mr. MacAlister the southern, with its adjoining granite. The fine-grained, hard, calcareous rocks, referred to in last year's SUMMARY as forming part of the Meadfoot series, have been more fully examined, and prove to form two distinct belts, one on either flank of the anticlinal axis of St. Columb Major and Watergate Bay; they appear, therefore, to be metamorphosed equivalents of the calcareous rocks found near Newquay, but if this is the case the fossils have entirely disappeared.

rrow. In the northern belt, owing to incessant repetition by folding, these calcareous strata have a very broad outcrop, often more than a mile across. Within this, however, infolds of the adjacent soft killas occur, and these, where practicable, have been separated out on the map. The whole of this folded rock-mass has been trenched open to the east of Withiel by a stream flowing northward across the strike; so that an almost complete section of the series is exposed. In addition to this, two large quarries (Tremore Quarries) have been opened in the banks of this stream, and in them the flinty calcareous

rocks are quarried for road metal; they can therefore be examined in minute detail.

The dominant component of the whole is a hard, flinty, or horny rock (for which type the term "calc-flinta" has been used in Scotland), which occurs in very thin bands of tint incessantly varying, though generally pale-coloured. The tints vary from white to pale-yellow, buff, pinkish, and occasionally pale-green; and the texture varies from flinty or horny to very finely granular. This dominant type is essentially an admixture of very fine siliceous material with a varying percentage of lime, and the changes in tint and texture are essentially due to the varying proportion between the two components. A minor constituent is a dark-green rock, in which the lime was originally mixed with a siliceous mud; this contains a considerable amount of actinolite, and at times resembles a foliated basic igneous rock. Scattered through the whole mass are partings of brittle killas, differing from the last-mentioned rock in that the siliceous mud contained no lime. When even moderately altered, this killas asumes a brownish or purplish tint. It is the material which, nearer the granite, passes into flinty biotite hornfels, or into the fine biotite-schist so constantly associated with the calc-flinta.

Owing to the great hardness of these rocks, the most northerly band usually rises above the adjacent normal killas almost like a wall, and the feature thus formed can be well seen from St. Breock Down, stretching east and west for 10 miles. Though not the most persistent, it is the most sharply-defined geological feature in this part of Cornwall.

The effects of pneumatolitic action on the calcareous beds (calc-flinta) of the Meadfoot series (referred to in last year's SUMMARY, p. 32) have been further investigated. It has been found that over a considerable tract of ground, at least 14 miles long, axinite has been developed in considerable quantity, and at three localities where the calc-flinta has been quarried it has proved extremely abundant.

The Staddon Grits are separated from the group of beds last described by some dark non-calcareous killas, which passes gradually into fine-banded silts, in which the colour contrast in the films is well marked. The line between these silts and the group of rocks known as the Staddon Grits is obscured by wash, and not sharply defined. A fairly well-defined upper limit to the Staddon Grits occurs in this area, if the boundary is taken at the highest group of grit-bands; if, however, all outcrops of the banded silts are included in this group, the boundary at once becomes very difficult to draw, for on the coast the bands of softer killas associated with these silts contain Middle Devonian fossils. The explanation of the difficulty may be that the banded silts are really the highest beds of the Lower Devonian, but are repeatedly infolded with the basement beds of the Middle Devonian; in other words, the junction is repeated by fold-

ing. Were the ground clear enough to be mapped in minute detail, the map would show a series of parallel narrow strips, alternately of Middle and Lower Devonian age.

Mr. Mac-Alister. In the southern part of this area, in the neighbourhood of Roche, the proximity of the Meadfoot beds to the St. Austell granite brings them within the zone of metamorphism surrounding that intrusion, with the result that metamorphic types corresponding with different members of the Meadfoot group are found. The sediments consist of finely-banded slates in which very thin bands of siliceous material alternate with argillaceous layers. The cleavage in most cases is coincident with the bedding. Owing to the gritty nature of much of the material the metamorphism, which was intense enough to develop andalusite and mica in the more argillaceous rocks, appears scarcely to have affected it.

The most remarkable rocks of this region are the hornstone or calc-flinta bands, which in the district westward, free from all effects of contact metamorphism, are represented by calcareous bands impossible to map. In the metamorphic area east and west of Goss Moor, however, the hornstones are readily differentiated from the rest of the Meadfoot series, and two prominent bands have been mapped. One extends from the south of the Roche Rock, westward through Innescaven, Gaverigan, and Indian Queen to Fraddon. The other, further north, extends from Tregoss westward to Ruthvoes and Trevarren. These beds, however, are not always represented as hard hornstones in the metamorphic zone, as here and there they consist of rotted material of yellowish-white colour.

### *Altered Rocks of the Metamorphic Zone.*

In addition to the alteration effected in the sedimentary rocks by contact with the granite, this region has been invaded to an exceptional extent by vapours containing fluorine and boron, which were given off by the granite during its consolidation. The mineralization caused by these vapours is part of the pneumatolytic action connected with the formation of the tin-lodes, and possibly also with the change of the felspar of the granite into china-clay. Although ordinary greisen action, with the production of topaz, white mica and other minerals, is common, the most prominent feature is the remarkable development of tourmaline in the rocks which are fractured or are traversed by veins.

Near the village of Roche, not far from the granite margin, is situated the celebrated Roche Rock, which projects as a rugged bare rock-mass to a height of over 60 feet above the surrounding plain. Although it appears originally to have been a granite of medium grain, it now consists of a mass of quartz and schorl of remarkably uniform texture, traversed by numerous joints. In some cases the joints are filled with schorl, on each side of which the rock is very

schorlaceous, but shades off into a more siliceous aggregate of quartz and schorl at a distance from the joint. The tourmaline is mainly of the blue variety, but the interior of many crystals is brown, while some basal sections are seen to be banded with blue and brown. At the southern margin of the rock a trial for china-clay was made some years ago owing to the discovery of kaolin mixed with the schorl-rock. At the northern margin of the rock, about 100 yards from the road between Roche and Carbis, a tourmalinized killas breccia cemented by quartz can be seen.

A point of particular interest is the relation of the Roche Rock to the beds of hornstone above mentioned. The intrusion of the granite apophysis from which the rock was derived seems to have taken place at one side of the hornstone, along which there was probably a line of weakness.

In the main mass of the granite tourmalinization can be seen in all its stages, from nearly fresh granite to schorl-rock. In the parish of Luxulyan the well-known luxullianite represents an intrmediate stage of the conversion.

In the sedimentary rock tourmalinization only occurs along the argillaceous bands in the neighbourhood of veins; the more siliceous bands have been scarcely affected. These tourmalinized sediments are very hard, and are utilized for road-making in some places. As some of the rocks are much folded and contorted, these structures are well preserved and brought out in full contrast by the tourmalinization of the argillaceous bands between the gritty layers.

## GRANITE.

The character of the normal granite of St. Austell is well known, and the altered rock has been described incidentally in the last section. An extremely coarse vein of pegmatite, about 50 yards in width, occurs in the killas a few yards from the granite margin at Tresayes Downs. It consists of enormous orthoclase crystals, roughly parallel and arranged vertically; some of them are intergrown with quartz. Some quartz occurs interstitially, and is frequently associated with tourmaline, a little fluorspar and white mica. The vein has a north and south bearing, parallel with the granite margin at this place. This pegmatite was formerly worked as a large open pit for felspar used in glass-making, but the work was abandoned about 1880.

On St. Dennis Downs there is a very coarse vein of dark-brown mica which is here and there associated with pegmatitic felspar and quartz. As these micas are usually lithia-bearing, and there is a demand for lithia which cannot be supplied from this country, an analysis was made by Dr. Pollard, who found that a sample of the material contains 1.51% of lithia ($Li_2O$). About 5% is apparently the minimum quantity that pays to work. Mica-veins are of rare occurrence in Cornwall. Dr. Pollar

Mr. Barrow. In Bodmin Moor at least three good-sized masses of fi granite, similar to the newer granite of Scilly and Land's En have been met with. This finer rock on Bodmin Moor, li the rock in West Cornwall, is clearly intrusive, for near junction with the normal granite the latter is permeated veins of finer material. As a rule, the potash-felspars in t latter are quite small, but sporadically they become larg and at times are fairly numerous. The characteristic differe tial feature of the finer intrusive granite is the almost ent elimination of the coarser grains of quartz, so abundant the normal granite, whatever be the size of its potash felspa

### MIDDLE AND UPPER DEVONIAN.

Mr. Reid. The region south of the Camel exhibits a belt two or thr miles wide of Middle Devonian strata; but the whole depo consists of grey, more or less calcareous slate, about which lit can be said till the fossils have been more thoroughly exa ined. Any detailed account is the less needed in that M Howard Fox has recently published an excellent descripti of the coast section in the *Transactions of the Royal Geologi Society of Cornwall*. Middle Devonian fossils are traceal northward as far as Constantine Bay, and, as Mr. Fox h shown, Upper Devonian species come on in Booby Bay; b there is an intervening area in which nothing characteris can be found, and part of this area is hidden by dune a sand-flat. Unfortunately, it appears to be through this hidd area that the line between Middle and Upper Devonian mu be drawn.

A short distance inland from Constantine Bay, if we foll the strike to the east-south-east, we discover along the li of these hidden strata a narrow band of volcanic tuff, whi has been taken provisionally as a convenient base for t Upper Devonian. At any rate, if it does not exactly coinci with the junction, it forms a useful horizon, for below it contemporaneous volcanic rocks occur, while at and abo this line both tuffs and lava-flows form a marked feature. other lithological change in the slates themselves coincid with the palæontological one, for the grey slates containi *Buchiola retrostriata* (v. Buch.), [*Cardiola* (Auct.)] a scarcely distinguishable from the Middle Devonian sla below. Somewhat higher in the series, however, the Upp Devonian slates take on marked characters; but it is n till certain purple and green strata are reached that meet with any striking lithological change.

Messrs. Reid and Dewey. The band of tuff which has been taken as the provisio boundary is traceable at short intervals all the way to Wad bridge, near which place it crosses the River Camel, tu north-north-eastward, and is continued in a thick mass of la and tuff intermixed.

The Upper Devonian strata of the Camel Valley, unlike t Middle Devonian slates further south, are variable both

lithological character and fossils. They commence in Booby Bay with banded grey slates with few fossils, except indeterminable *Tentaculites* and *Conularia*; though these ill-defined strata may perhaps be referable to the Middle Devonian. North of these, and passing gradually into them, we find more calcareous slates with thin limestones; the slates yielding *Buchiola retrostriata* and long slender crinoids. Trevose Head shows very calcareous slates with *Styliola*, alternating with thin limestones and chert-bands, containing the characteristic Upper Devonian form of *Phillipsastræa*. Then follow more grey slates and limestones, very like those of the Middle Devonian, so that it is a good way up in the series before we come to the strikingly different non-calcareous purple and green strata, which form so marked a feature in the Upper Devonian succession in this part of Cornwall.

Mr. Dewe

Though the examination of this area is still unfinished, the mapping has brought out the main tectonic features. A succession of closely-packed isoclinal folds, with southerly dipping limbs and east and west strikes, is thrown into a synclinal fold with an axis trending north of west. Series of sills exemplify this structure, and occur in narrow east and west bands along a mile-wide strip of country, running north-westward from Wadebridge through Burniere and Trevelver to Trefresa. The trend of the junction between grey slates and variegated slates follows a similar direction, and corresponds with that of the assemblage of lenticles of contemporaneous volcanic rocks of the Trelill and Endellion district.

### *Igneous Rocks in the Upper and Middle Devonian.*

Messrs. R and Dewe

The igneous rocks of the Camel Valley turn out to be much more varied than has been thought, and among them have been found dykes of mica-trap or lamprophyre probably of Permian age. Dykes of this comparatively recent date do not appear previously to have been recognized in this area, though they are well known near Newquay and Falmouth. This discovery may help to link on the dykes of West Cornwall with the traps of Exeter. The description of the various igneous rocks will be reserved till they have been more thoroughly examined under the microscope.

## ECONOMICS.

### *Tin-mining.*

Mr. Reid.

The examination of two tin-bearing districts was continued during 1906, and in each of them there is sign of a revival of the industry, though both Bodmin and St. Austell Moor were more noted for stream-tin than for tin-lodes. Most of the stream-tin has long since been removed, but perhaps part of it remains, especially in the deeper channels crossing wide swampy flats, over which it was difficult to remove the water without modern appliances.

Mr. Bar

On Bodmin Moor, in both coarse and fine granite, greisen-

lines and schorl-rock are fairly common over all the area examined during the past season, and in some portions of it are extremely abundant. It seems clear that whenever schorl-rock occurs in the Bodmin Moor granite it is accompanied by considerable quantities of tin-ore, which, however, occurs mostly in strings or short discontinuous veins; for over a large part of the area there are no tin-mines in the modern sense of the term. As the granite decomposed, the tin-ore was set free and was washed down the hillsides, and accumulated in the flat-bottomed valleys. These flat-bottomed valleys are a feature of the Bodmin Moor granite, and there can be little doubt that their slow fall has aided in the retention of the heavy tin-ore. In all such valleys, except in the special area referred to on p. 31 of last year's SUMMARY, tin-ore has been formerly met with in abundance. This stream-tin did not, however, cover the whole of the flat-bottomed valley, but in payable quantity was confined to slightly deeper and narrower channels, the positions of which are marked at the present surface by a belt of small mounds, composed of material turned up in extracting the ore. In the part of the granite west of the Fowey, which has now been surveyed, if the lengths of the tin-bearing belts of gravel be added together, they would amount to at least 50 miles; a fact that throws considerable light on the enormous length of time during which stream-tin was worked in Cornwall—nearly 2,000 years.

In some cases a considerable amount of stream-tin has been found in quite small runnels and small slacks; on the open moor, where the ground has been undisturbed, traces of shallow workings in small strings show that the local accumulation has been washed down from these strings as the granite decomposed; in the majority of such runnels no appreciable quantity of ore has been found.

The occurrence of these strings or short veins not sufficiently continuous or rich enough to justify the starting of a regular mine is a feature of the south-west portion of the Bodmin Moor granite. There is a distinct tendency for these strings to occur in groups, and in such case the whole ground is studded over with old shallow pits, which seem to have paid so long as the granite remained soft and easily worked. In many cases, in such areas, a deeper shaft has been sunk on one of the more continuous veins, but in most cases without success. Where such an area has been mined by nature, as the granite decomposed, exceptionally large quantities of stream-tin have been produced, which gradually found its way to the bottom of the valleys.

The most perfect example of an area permeated by these strings occurs on Goonzion Down, west of St. Neot, where the containing rock is killas. There must be some 200 pits, large and small, in a comparatively small area, and of these by far the greater number were quite shallow. Here and there, however, larger tip-heaps occur, arranged in lines, marking the site of a more continuous vein, which paid to

work to a greater depth and in somewhat harder rock. A few deep shafts have been sunk on two of these, but no extensive work was carried on from them, though, possibly, this may be in part due to the low price of tin at the time they were sunk, for it is proposed to re-open one of them.

In a large number of cases the tin-ore in these strings occurred in fair-sized crystals, packed pretty close together, and not finely disseminated through schorl-rock or peach. The finest examples of bunches or lenticles of well-crystallized tin-ore seem to have been met with in one of the elvans, about a mile to the north of St. Neot, considerable patches of the elvan, where the tin was found, being altered to greisen. A large quantity of this elvan was mined for tin, but these bunches were so far apart and irregularly distributed that the rich patches did not pay for the extraction of the large masses of barren rock.

The high price of tin has led to the further development of some of the mines in the area surveyed during the past season, and to arrangements being made for re-starting others that have been shut down for some time. Great additions have been made to the plant at Mulberry Mine, which lies about four miles south-west of Bodmin. This, like Lanivet, is one of the few open-work tin-mines, and really consists of a huge trench, now some 200 feet deep, which is unwatered by a long adit, driven from the foot of the hill at the crest of which the mine is situated. The killas here is traversed by a vast number of minute cracks trending north-north-east, along which pneumatolytic action has taken place, the killas being tourmalinized, and tin-ore in small crystals deposited on the face of many of the cracks. Much of the rock is taken out solidly and stamped up, the tin being thus set free and washed out. In addition to the tin-ore, copper and wolfram are also present. Mulberry Mine presents a strange phenomenon; as already stated, the killas is here traversed by a vast number of minute cracks trending north-north-east, but the belt of ground within which these cracks contain a considerable amount of tin-ore trends nearly due north and south, or at right angles to the normal trend of a tin-vein; moreover, there does not appear to be any distinct north and south vein, or master-crack, in or parallel to the belt of paying ground. At Lanivet, the other open mine where work is proceeding as usual, a vast number of minute cracks are also present, but here trend east and west, and there does appear to be a master-vein present, at any rate in some part of the mine. The open workings are nearly a mile in length, and the tin does not appear to be accompanied by much copper-ore or wolfram, so far as could be ascertained.

Mr. Mac Alister.

Nowhere in Cornwall have the tin-bearing alluvia been so extensively worked or yielded so much tin-ore as those of the region on the northern border and central part of the St. Austell granite. The tin-gravels occur in wide detrital flats (or mosses), locally termed "moors," and in the valleys leading

to them. Both have been explored by former tin-streamers, who have left heaps of débris and pits now filled with water; but the pits were all abandoned in the early part of last century, or fitfully worked up to thirty years ago. These stanniferous alluvia are entirely confined to the mining areas or to the streams leading from them.

By far the greater part of the deposits is non-stanniferous, and it is only the lowest few feet, or that resting upon the solid ground, or "shelf," which contains tin-gravels, and even this was not uniformly productive. The distribution of the richer patches of stream-tin is to a certain extent dependent on the shape of the surface of the solid ground, and the alluvia are particularly productive at places where several streams meet.

Although the surface of the deposits on the large open moors, such as Goss Moor, is an almost level plain with a gentle slope towards the outlet, the surface of the bed-rock below is very irregular. The richest tin-ore occurs in erosion channels and hollows in the bed-rock or "shelf." The "leads" so formed have frequently been known to contain several per cent. of black tin. Owing to the amount of washing and weathering which the detritus has undergone in reaching its present position the grain-tin is remarkably pure and free from the sulphides commonly associated with the ore in the lode.

If the whole of the material could be removed from one of these moorland basins it would appear as a wide shallow hollow, with an irregular floor cut into here and there by water-courses. It is even stated that the slope at certain places is as much as 45°, an amount which exceeds that of any part of the present surface of the surrounding country. Detrital tin-ore, however, is not confined to these moorland hollows, but, as at Kerrow Moor, has frequently been followed out of them and worked on the gentle drainage-slopes leading to them. This 'shoad' material merges insensibly into the alluvia of the moors.

The present high price of tin and the exhaustion of most of the alluvial deposits makes it advisable to look about for other sources of supply. One source seems to have been overlooked, or, at any rate, nothing appears to have been done to tap it. There must be a large amount of detrital tin-ore at the bottom of certain of the bays margined by rich tin-lodes. For instance, there is St. Ives Bay, which has received the detritus from the rich lodes of St. Ives Consols and Wheal Providence, and there is Mount's Bay, bordered by numerous smaller mines. Of course, with the old-fashioned bucket dredge it would be impossible to reach the rich tin-ground which lies mainly in narrow rocky channels beneath the sea-sand, and this is probably the reason why nothing has been attempted. With modern appliances and sand-pumps, part at least of this valuable deposit might be reached.

If anything is to be done along this line it becomes a question where is the tin likely to be found? The main mass lies

probably in deep channels much below the sea-level and smothered by shell-sand, and these channels will almost certainly continue seaward with the same bearing as the existing valleys, of which they are only the submerged lower parts. The tin-ore, perhaps, lies too deep to win, unless the dredging can be combined with the improving and deepening of the harbours by clearing out these submerged channels to their full depth, or with the sale of the overlying sand, which is a valuable manure. The probably maximum depth of these old channels beneath the sea-level is about 60 feet.

Antimony also is in increased demand, and some of the small mines near Wadebridge are being re-opened. The question arose whether these mixed antimony- and lead-ores might not contain sufficient silver to be worth taking into account, at any rate as a bye-product. Dr. Pollard was therefore asked to examine a sample of the Jamesonite from Trevinnick Mine, St. Endellion. On assay it yielded 2 ozs. 16 dwts. of silver per long ton. Dr. Pollard

The curious discovery that the ferruginous gossan in a small north and south lode at Perranuthnoe is a rich silver-ore, suggests that in other cases gossans above lead-lodes should be examined for the concentrated silver left after the removal of the lead. In this instance Mr. G. D. McGrigor, the manager of the mine, was interested in mineralogy, and happened to notice small pale-green crystals in the soft earthy gossan, and these turned out to be chloride of silver; but no one would otherwise have suspected the occurrence of chloride and bromide of silver in a poor iron-lode. Mr. Reid.

Mention has above been made of the search for platinum in conglomerates derived from basic igneous rocks. Thus far, it has been without success; but other assays will be made.

## III.—South Wales District—Pembrokeshire.

Dr. Aubrey Strahan, M.A., F.R.S., District Geologist.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A., B.Sc.
Mr. O. T. Jones, M.A., B.Sc. } Geologists.

The field-work of 1906 lay in the Ordovician tract around Whitland, Narberth and Haverfordwest, in the Old Red Sandstone and Lower Carboniferous rocks near Slebech and around Pembroke, and in the Coal-measures near Martletwy and Saundersfoot.

### ORDOVICIAN.

Field-work in the Ordovician and Silurian rocks was carried on in the neighbourhood of Whitland, Narberth, and Haverfordwest, a district described by Marr and Roberts* in 1885. The following table shows in descending order the succession of the rocks below the Old Red Sandstone:—

| | | |
|---|---|---|
| Silurian (part). | Llandovery. | *Lower Llandovery.*—Grey and olive-green mudstones with occasional bands of grey sandstone and conglomerate. Fossils occur locally, but are rare at base. |
| Ordovician. | Bala | *Slade and Redhill Beds.*—Blue-grey mudstones with bands of decalcified sandy mudstone and some micaceous sandstone; corals, crinoids, and brachiopods locally abundant.<br>*Shoalshook and Robeston Wathen Limestones.*—Dark thin-bedded limestones, with *Cybele verrucosa*, *Encrinurus sexcostatus*, *Illænus bowmanni*, *Halysites catenularia*, &c.<br>*Dicranograptus Shales.*—(*a*) *Lower Hartfell Stage.* Black pyritous shales, including possibly the lower part of the zone of *Pleurograptus linearis*, together with the zones of *Dicranograptus clingani* and *Climacograptus wilsoni*. |
| | Llandilo | *Dicranograptus Shales.*—(*b*) *Glenkiln Stage.* Black shales and shaly limestone (Mydrim Limestone), with *Didymograptus superstes* and other fossils of the *Nemagraptus gracilis* zone.<br>*Llandilo Flags.*—Sandy flags and sandy limestones with *Ogygia buchi*, *Asaphus tyrannus* and other Llandilo forms. |
| | Arenig | *Didymograptus bifidus Beds.*—Blue-black soft shales with *D. bifidus* and other forms characteristic of Dr. Hicks's Lower Llanvirn fauna. Ash-beds are present locally.<br>*Tetragraptus Beds.*—Blue-black iridescent-weathering shales and blue mudstones with *Didymograptus hirundo*, *D. extensus*, *D. nitidus*, *Tetragraptus*, &c. Fossiliferous and conglomeratic grits towards the base. Shales with *Ogygia marginata* and grits with abundant *Orthis*. |

* *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 476.

*Tetragraptus Beds.*—From the district of Henllan Amgoed, described in last year's SUMMARY OF PROGRESS, these beds have been traced by way of Llanfallteg to Llandissilio West, from whence they continue along the northern margin of the area now being surveyed. A little to the west of Henllan Amgoed the westerly pitch of the Henllan anticlinal system causes the upper shale-division of the *Tetragraptus* beds to wrap round the older gritty series; the *Orthis* grits finally disappearing to the south of Henllan Church. The upper shales occupy the country to the north of Llanfallteg, and are well exposed all up the valley of the Tâf; but they show signs of considerable disturbance, and are often cleaved to the obliteration of the bedding. Crossing the Tâf, these shales may be traced to Rhyd-wen, and are probably faulted on their southern margin against *D. bifidus*-beds. Further west their structure becomes exceedingly complex, the *Tetragraptus*-beds being folded and faulted and occurring as lenticular masses bounded on all sides by *D. bifidus*-shales; such faulted inliers are especially noticeable to the west of Rhyd-wen, near Bryn-aeron, and Dyffryn Trogyn. To the north of Llandissilio West an anticline with a westerly pitch causes the southern limit of the outcrop to turn abruptly northwards, parallel to the River Cleddau. This boundary, which is here normal, is cut by a strong east and west fault, which to the west keeps *Tetragraptus*-beds on the north side of it and *D. bifidus*-shales on the south. Mr. Thoma

From the River Cleddau the lower shales may be traced to Rhyd-y-Brown, through and to the south of Walton East, through Scolton Cross and Spittal Village to the new line to Fishguard, where they are exposed in, and at the south end of, the tunnel; here they occupy a position between the igneous rocks (pre-Cambrian as supposed) on the north, and the *D. bifidus*-shales on the south. To the west of the Western Cleddau they occur as a faulted lenticle on the south of the igneous rocks of Wolfsdale, and are overthrust on to the *Dicranograptus*-shales; they have yielded *Didymograptus hirundo* (Salt.) and other extensiform graptolites.

*Didymograptus bifidus Beds.*—*D. bifidus*-shales occupy the country around Llanfallteg and the district lying between Clynderwen House and the *Tetragraptus*-beds to the north. Faulted outliers occur in the *Tetragraptus*-shales at Bryn-aeron and Dyffryn-Trogyn. Westwards they pass to the north of Egremont, and crossing the River Cleddau may be traced to the north of Bletherston by way of Pen-ffordd, to the north of Clarbeston Village, through Penty Park, and along the new line to Fishguard, where they are well exposed in the long cutting at Lower Haythog. On the south they are invariably overthrust on to *Dicranograptus*-shales. To the west of Scolton they are faulted out, the *Tetragraptus*-shales being thrust over them onto the *Dicranograptus*-shales; but in the cutting leading to the tunnel under Spittal Road bridge they again come to the surface as a lenticle lying between the above-

named formations. This mass of shales is not more than 400 yards long by 100 yards in width. At Rhyd-y-Brown interbedded ashes, which become stronger as they are traced westwards, occur on about the same horizon as those already described in previous Summaries. They reach their maximum development to the north of Clarbeston Village, and here form a conspicuous ridge running by Penty Park and Upper Haythog to Scolton, where they are faulted out. They appear again, however, in the railway-cutting at Spittal Road.

rill. These shales and ashes form the core of an anticline which extends westward from Whitland towards Narberth along the course of Lampeter Vale. Fossils, notably a small form of *Didymograptus*, are specially abundant in densely black shales at the summit of the sub-division. Occasional thin beds of ashes occur, as for example north of Lampeter Velfrey. *D. bifidus*-beds extend westward from Clynderwen to beyond Egremont.

nas. *Llandilo Flags.*—A limestone, to the south of Clynderwen House, is succeeded by black *Dicranograptus*-shales, and underlain by *D. bifidus*-beds; it must therefore be referred to the Llandilo series, although it is practically unfossiliferous. It is folded into a gentle anticline, with an east and west axis and a westerly pitch, which causes the outcrop to double back on itself and to leave the ground on the west occupied by *Dicranograptus*-shales. Two other outcrops of flags and limestone, both inverted from the north, occur to the west; one between Bletherston and New Mill in the Syfynwy Valley, and another opposite and west of New Mill, where the rottenstones yielded an *Ogygia*, and other fossils of Llandilo character.

rill. Along the north side of Lampeter Vale the *D. bifidus*-beds are succeeded by a thin group of earthy flags and impure limestones, yielding some of the usual Llandilo fossils. The group thickens westward between Whitland and Llanddewi Velfrey, and also southward across Lampeter Vale. The rock is quarried for roadstone, and was formerly burnt for lime.

A thin representative of the Llandilo Limestone is present between the *D. bifidus*-beds and the *Dicranograptus*-shales near Clynderwen and Egremont, though it has yielded nothing but a fragmentary *Orthis*. Even-bedded blue-black limestones underlying the *Dicranograptus*-shales are brought up as an elongated dome at Bullhook, near Clarbeston, though here again they have yielded no fossils.

s. The Llandilo Flag series is repeatedly exposed to the west of the main road from Narberth Station to Penblewin. As around Lampeter Velfrey, it consists of tough blue limestone in the lower part, followed by dark-grey calcareous flags, weathering to a brown or buff rottenstone. *Trinucleus*, *Asaphus*, and brachiopods are extremely abundant in some flaggy sandy limestones at the base. Upwards, the flags become thinner-bedded, and finally pass into black yellow-weathering sandy shales; the depth to which the weathering extends diminishes in ascending the sequence, until finally only a

yellowish-white skin is formed. Thus they pass up into the black *Dicranograptus*-shales. These changes are well seen in an old lane leading from Stoneyford to Blaenffynonau. The series is probably only about 250 feet thick, but it covers a considerable amount of ground to the north of Narberth, as a result of repeated folding and faulting. These structures will be referred to under Faults and Disturbances. Mr. Cantrill

*Dicranograptus Shales.*—The Llandilo flags and limestones pass upwards into black shales characterized by species of *Dicranograptus*, *Diplograptus*, and *Climacograptus*. During the past season, with the assistance of Miss G. L. Elles, efforts have been made to identify the various zones included in this group, with the result that the lower part can now be assigned to the Glenkiln stage of the Llandilo, and the upper to the Lower Hartfell stage of the Bala.

The *Dicranograptus*-shales form a narrow belt running along the north side of Lampeter Vale, being exposed at numerous points between Trewern and Llanddewi Velfrey, where they are characterised by *Dicranograptus nicholsoni* (Hopk.), *Dicrano. tardiusculus* (E. and W.), and *Dicellograptus sextans* (Hall), and are thus referable to the highest horizons of the Glenkiln.

West of Clynderwen the *Dicranograptus*-shales occupy a belt of country traversed by the Great Western Railway as far as Clarbeston Road Station; several of the cuttings afford good sections.

*Dicranograptus*-shales occur to the immediate south of the *D. bifidus*-beds, and may be traced from Whitland to the Western Cleddau by way of Bletherston and Clarbeston. To the south of Wolfsdale they underlie the *Tetragraptus*-beds, which have been thrust over them from the north. The *Dicranograptus*-shales include the Glenkiln and most of the Lower Hartfell horizons; the zones of *Nemagraptus gracilis*, *Climacograptus wilsoni*, *Dicranograptus clingani*, with possibly the lower part of the *Pleurograptus linearis*-zone being represented in various parts of the district. Mr. Thomas

The Glenkiln Shales are exposed at Tyncoed west of Trewern near Whitland, south of the Llandilo Flags near Bletherston, west of New Mill, and in the railway-cutting at Spittal. Opposite New Mill they contain bands of rottenstone, and have yielded slabs crowded with *Nemagraptus gracilis*, (Hall), *Didymograptus superstes* (Lapw.), *Dicranograptus nicholsoni* (Hopk.), and *Dicellograptus sextans* (Hall).

In the Spittal cutting the lowest beds seen are limestones and shales containing *D. superstes*, *Leptograptus*, *Dicellograptus sextans*, etc., a fauna identical with that of the Mydrim Limestone north of St. Clears, and of the Stinchar Limestone of the Girvan district. These beds are followed by the lower zones of the Hartfell shales, and in the cutting, although the rocks are much faulted and overthrust, representatives of the *Climacograptus wilsoni* and *Dicranograptus clingani* zones may be detected. The highest beds recognized

yield *D. clingani* (Carr.), and *Dicellograptus forchammeri* (Gein.).

Mr. Jones. In the Narberth district, as stated above, these follow on the upper part of the Llandilo Flags, which pass gradually into them. Their thickness varies greatly. In the old lane section already mentioned they are certainly not more than 50 feet thick, while less than half a mile to the north they are probably between 200 and 300 feet. They are found underneath the Bala Limestone to the north of Robeston Wathen, where they contain graptolites; there is room for about 70 or 80 feet between them and the bottom of the limestone. Their base nowhere reaches the surface in this neighbourhood, so that their thickness is not known. To the south of Llawhaden also there is an irregular dome of these rocks, about two miles long and half a mile wide, ranging east and west.

Mr. Cantrill. *Robeston Wathen and Shoalshook Limestones.*—West of Whitland the *Dicranograptus*-shales are overlain by a band of blue-black limestone of Robeston Wathen type, quarried at Trewern and Fron. This limestone can be traced as far as Upper Fron, but west of this point it is absent, and at Llanddewi Velfrey the Redhill and Slade Beds rest directly on the *Dicranograptus*-shales. The fact that here the highest of these shales yield *Dicranograptus nicholsoni* indicates that there is a considerable overstep, the Lower Hartfell Beds with *Dicranograptus clingani*, though present at St. Clears, being here absent.

The Robeston Wathen type of limestone has been quarried at Grondre, north of Narberth, but between Egremont and Clarbeston Road Station no limestone is present.

Mr. Jones. In the dingle north of the church of Robeston Wathen the *Dicranograptus*-shales are followed, after a small gap, by the limestone exposed in the old quarry, which lies on the east side of the dingle. This quarry was selected by Marr and Roberts* for their type-locality.

The north side of the quarry is in a fine-grained blue limestone with intercalated black calcareous shale; in the lower part of the quarry the shale-bands are thin, but are relatively more important in the upper part, while the limestone is less pure. *Halysites catenularia* (Linn.) is abundant in the shale-bands. A Cystidean and several specimens of a large *Petraia* were found near the top of the limestone. The calcareous beds end abruptly about 15 feet from the top of the quarry, and blue mudstones of an entirely different lithological type follow without any alternation. The thickness of the limestone is about 70 feet. A rock, agreeing in its lithological characters with the above, and containing the same fossils, has been extensively quarried along the dingle about a quarter of a mile south-west of Grondre. It is there folded into a deep syncline underlain by *Dicranograptus*-shales. The rock was quarried for burning,

* *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 479.

but this was discontinued between twenty and thirty years ago.

On the south and east of Robeston Wathen the Redhill and Slade Beds rest on yellow sandy rottenstones, which are faulted against Lower Llandovery rocks. The rottenstones may be the weathered equivalents of the Robeston Wathen Limestone, or may be only an impure calcareous base of the blue mudstones, such as occurs in other parts of the district.

In a dingle a quarter of a mile west of Pont Shan the *Dicranograptus*-shales are succeeded suddenly by greenish impure ferruginous limestones, interbedded with blue mudstones. Calcareous nodules are frequent, and there is one band of fairly pure limestone. Fossils are not uncommon, and include a *Trinucleus*. The underlying *Dicranograptus*-shales are disturbed, but there is probably no fault at the junction. The calcareous band is about 30 feet thick, and passes up gradually into greenish-blue mudstones with calcareous fossiliferous bands. In its lithological characters and its gradual passage up into the mudstones this development resembles Shoalshook rather than the Robeston Wathen Limestone, and although the quarry at the latter place is only half a mile to the south of this section, that type of limestone does not appear to be represented.

*Redhill and Slade Beds.*—These blue-grey mudstones succeed the Bala Limestone, or, in its absence, the *Dicranograptus*-shales. They are well developed between Whitland and Llanddewi Velfrey, and are fairly fossiliferous, though the Slade Beds are often unrecognizable. West of Clynderwen the whole group is remarkably homogeneous and unfossiliferous. Mr. Cant

These beds come to the surface from beneath the drift near Castelldwyran, and continue westwards to the main road at, and to the north of, Longford. Mr. Tho

At Clarbeston Road a gently undulating series succeeds, to the south, the *Dicranograptus*-shales. The two deposits are probably faulted together, but the break need not be large. Traced southwards, these beds pass gradually upwards into the Lower Llandovery rocks of Wiston.

In the Narberth district it seems possible to distinguish a northern and a southern type of these beds. The change is noticeable on crossing a complex disturbance, which ranges in a west-south-westerly direction along the valley of the River Develidge, and passes about three-quarters of a mile south of Llawhaden; so far as it has been followed at present it then has a direction a little south of west for about three miles. Mr. Jon

The rocks of the southern type are well represented around Narberth and Robeston Wathen. They consist of grey and blue mudstones, with frequent thin greenish micaceous bands showing uneven dark laminæ on a cross fracture. They include, also, somewhat thicker grey and brown micaceous sandstones, with a prominent jointing, which causes them to

break up into sharp-edged triangular prisms. These, together with bands of fossiliferous rottenstones, are characteristic of the upper part of the group, while the greenish micaceous sandstones are more usual in the lower part. Fossils are common throughout, but are more abundant in the upper beds. The thickness of the group varies from about 650 feet on Blackmoor Hill, north of Narberth, to about 500 feet near Robeston Wathen.

The rocks which succeed the *Dicranograptus*-shales or Bala Limestone north of the Develidge disturbance are blue-grey mudstones with an occasional hard blue band and scarcely vary from top to bottom of the group; they are also almost devoid of fossils. Good sections occur to the south and east of Llawhaden.

SILURIAN.

Mr. Cantrill. *Lower Llandovery.*—The beds which follow the Redhill and Slade group are generally introduced by a conglomerate or sandstone, as is the case at Pale Mountain, near St. Clears, and also at the outlier at Wheelabout. In the absence of the conglomerate or sandstone it becomes extremely difficult to define the base of these supposed Lower Llandovery rocks, particularly where the Slade group is unrecognisable, as there is little difference between the mudstones of the two groups. The Lower Llandovery thus appears to have been introduced without any great change of conditions. There are, however, several facts which show that a certain amount of unconformity marked its incoming. A band of conglomerate, about 200 feet above the base of the Lower Llandovery, near Llawhaden, contains numerous pebbles of fossiliferous *Dicranograptus*-shales, which can be paralleled with outcrops of Glenkiln shales in the neighbourhood; so that it is clear that not far away the Lower Llandovery once overstepped the whole of the Bala, and rested directly on rocks of Llandilo age. It is possible also that our failure to recognize Slade Beds may be due to their local absence through overstep.

Mr. Thomas. The Lower Llandovery, with its basal sandstones and succeeding black shales and olive-weathering mudstones, occupies a synclinal area ranging from Wiston to the Rath at Hareshead, where an almost circular outlier of the lower sandstone group forms the top of the hill. The Hareshead outlier is the most westerly occurrence of Llandovery rocks yet met with to the north of Haverfordwest.

Mr. Jones. A thick series of rocks attributed to this formation covers a large area between Narberth and Haverfordwest. Near Narberth they are so folded and repeated by strike-faulting that there are no less than ten outcrops of the basal sandstones in a distance of two miles from north to south. The basal beds consist of grey sandstones and impersistent conglomerates, associated with blue-black shales. These are followed by blue, yellowish-weathering mudstones, with occasional sandy micaceous bands. Fossils are abundant on certain horizons,

but much of the lower part of the formation appears to be almost barren. The conglomerate reaches its greatest development near Robeston Wathen, where it has a thickness of 70 to 80 feet; westwards, this diminishes to about 15 feet in a distance of less than half a mile. As in the underlying Redhill and Slade group, fossils which are fairly abundant in the southern part of the Narberth district are almost absent in the northern part.

To the south of Haverfordwest, rocks which are provisionally referred to the Llandovery group occupy an extensive area; they consist chiefly of olive-green and buff sandy mudstones, often showing concentric weathering. To the south of that area there are pale greenish-blue shaly mudstones. The uppermost part of these is distinguished by the pasty character of the rocks, and by a band 5 to 10 feet thick of a deep maroon colour. Nearly all the beds have yielded fossils, which are undergoing examination.

### *Faults and Disturbances in the Silurian and Ordovician Tracts.*

All the faults in these tracts are strike-faults, mostly overthrust from the north. The largest met with throws *D. bifidus*-shales and *Tetragraptus*-beds on to *Dicranograptus*-shales. This thrust, which has the older beds on its northern side, has been traced for 16 miles in an east and west direction from Trewern near Whitland, to Wolfsdale north of Haverfordwest. It is exposed at the southern mouth of Spittal Tunnel, where it dips steeply to the north, and shows itself to be a fairly clean break unaccompanied by much crushing. Mr. Thom

Smaller faults involve the Llandilo Flags, *D. bifidus*-shales and *Dicranograptus*-shales near Clynderwen, Bletherston and Clarbeston.

A general east-and-west strike is maintained in the ground lying between Whitland and Haverfordwest, and the faults and thrusts take the same direction. Mr. Cantr

The well-marked anticline underlying Lampeter Vale has been traced westwards to the neighbourhood of Narberth, where it is arched over by a corrugated sheet of Llandilo Flags and Limestone, beneath which the underlying *D. bifidus*-beds are carried out of sight by the westerly pitch. The beds forming the northern limb of the anticline include the Llandilo Flags, *Dicranograptus*-shales, and Bala Limestone; the outcrops are much cut up by strike-faults, presumably overthrust from the north. The syncline which lies to the north of the anticline extends westwards through Commercial, and involves the Redhill and Slade and Lower Llandovery beds.

Another well-marked syncline begins near Clynderwen, and runs westward by Llawhaden and Wiston; and is specially well-marked in the Lower Llandovery beds.

To the north of Narberth the anticline which ranges along Lampeter Vale enters the Llandilo, Bala, and Lower Llan- Mr. Jone

dovery rocks. The structure can be studied in some detail, and is seen to be really an anticlinorium pitching to the west, accompanied by strike-faults of considerable magnitude, which take the general direction of the anticlinal and synclinal axes, and are nearly all downthrows to the south. It is best shown by the Lower Llandovery Sandstone, which forms a series of sharp zig-zag outcrops frequently displaced by the strike-faults.

Still farther north is the complex disturbance which follows the valley of the Develidge. It has a slightly different range from the others, and appears frequently to throw off branches having a direction widely diverging from that of the main disturbance. The valley has followed its course in a manner which calls to mind the Vale of Neath, and other valleys of West Glamorganshire.

The Robeston Wathen syncline of Bala and Llandovery rocks is bounded on the east and south by a curving overthrust, so that the older rocks have been pushed forward over strata high up in the Lower Llandovery.

### OLD RED SANDSTONE.

The separation of the Upper Old Red Sandstone from the Lower, and the subdivision of the latter into Ridgeway Conglomerate and Red Marl may be readily effected throughout the Lydstep-Pembroke syncline. The southward range of these divisions is not yet known, but to the north they are not distinguishable in the outcrop which extends from the Carew River, past Cosheston, to Hobbs Point. There the whole series consists chiefly of sandstones, in the upper part quartzitic and interbedded with breccias made up of many igneous rocks together with quartz and quartzite; in the lower and thicker part green, flaggy, micaceous sandstones predominate, which are often crowded with obscure plant-fragments. No other fossils have been found to determine to what part of the Old Red Sandstone these strata should be referred, nor has it become apparent from their relations to others in the district. The upper group closely resembles the Upper Old Red Sandstone of the more southerly outcrops in the characters of its breccias and sandstones, and the whole series is quite unlike the Lower Old Red Standstone of those outcrops. But at the same time, the lower group resembles the upper part of the Lower Old Red Sandstone of the more northern outcrop (Templeton, etc.) as described by Mr. O. T. Jones.* Also there is strong evidence that it is overlain with some unconformity by Lower Limestone Shales and thus differs from the Upper Old Red Sandstone. In view, therefore, of the conflicting nature of the evidence, the question of the age of these strata must remain for the present in abeyance.

It should be mentioned here that a comparison with the Old

* 'Summary of Progress' for 1905, p. 44. *Mem. Geol. Surv.*

Red Sandstone to the south, though the intervening distance is only half a mile, may be misleading, in that the two developments have been brought close together by a great strike-fault (p. 63). That this has brought very dissimilar facies of one formation into proximity is evidenced in the Carboniferous Limestone (p. 54).

## CARBONIFEROUS.

### *Carboniferous Limestone Series.*

As stated in the SUMMARY for 1905, there is an overlap at the base of this series, and an unconformity at the base of the 'Main Limestone' (*Seminula*-zone in part). As a result of these conditions the Lower Limestone Shales disappeared about three miles west of Templeton, thus bringing the beds of the *Seminula*-zone to rest directly on the Lower Old Red Sandstone. The fossil evidence suggests that from near Pendine westwards the base of the 'Main Limestone' has not always been at a constant horizon, for a *Caninia*, which is common in the Lower *Seminula*-zone ($S_1$), is not to be found in places, as though the whole or part of that zone were absent. From Templeton, westwards to the Eastern Cleddau, the thickness of the limestone rapidly diminishes almost to nothing, so that the base of the Millstone Grit nearly coincides with that of the limestone. From Slebech to Haroldston St. Issels, south of Haverfordwest, the thickness is less than 50 feet. Near Slebech and Minwear the greater part, if not the whole, of the limestone takes the form of a coarse-grained yellow dolomite, which from its character is almost certainly not of contemporaneous origin. At Millin, about two miles to the west, the limestone is quite undolomitized; there, and along its course to Haroldston, it is a dark-blue fine-grained rock, with some oolite, all belonging to the *Seminula*-zone, and probably to a low part of it. So far the cause of the dolomitization is not obvious. Mr. Jones

A section in an old limestone-quarry at Haroldston St. Issels seems to afford an explanation of the westerly thinning of the limestone. The Millstone Grit there rests on an uneven surface of limestone; the lower part of the lowest grit-bed roughly takes the form of the limestone surface, but the upper part does not, showing that the unevenness is not due to solution of the limestone and consequent collapse of the grit. The grit is fine-grained and siliceous, with the exception of a thin impersistent pebbly band. At some distance down in the limestone there are roughly lenticular patches of fine-grained grit elongated in the direction of bedding, and apparently isolated from the main mass.

This section leaves little room for doubt that the absence of the higher zones of the limestone towards the west is mainly due to an unconformity at the base of the Millstone Grit Series.

The basal beds of the limestone are visible near Millin. They consist of tough, pebbly, highly calcareous grits in beds up to two feet in thickness. The base is not seen, but they probably rest on olive-green Silurian mudstones, which are exposed about two yards to the north.

Work on the Carboniferous Limestone to the south of Milford Haven has been confined to the irregular anticline of which the northern and southern limbs extend past West Williamston and Pembroke Dock respectively, and to the Lydstep-Pembroke syncline to the south. Both limbs of the syncline show a conformable sequence throughout the limestone, but, as previously described,* the amount of contemporaneous dolomitization in the lower *Syringothyris*-subzone, *i.e.* in the *laminosa*-dolomites and *Caninia*-oolite, is greater in the northern limb than in the southern. In the Tenby-St. Florence outcrop, which lies to the north of the syncline, contemporaneous dolomitization at this horizon has been still more extensive, but in the anticline first mentioned, which is still further north, and in which, therefore, it was expected to be greater still, it is absent. Similar dolomitization, however, has affected practically the whole of the *Zaphrentis*-zone which immediately underlies the other horizon, and in which it is only slightly developed in the southern outcrops. The change in the *Syringothyris*-zone may be paralleled with what is observed in the Bristol district. There, dolomitization in the lower part of the zone increases northwards to a maximum in the Avon gorge, beyond which it diminishes, so that at Tytherington the rock beneath the *Caninia*-oolite is unaltered.† The cause of the change is probably the same in both districts, and is possibly connected with the existence of an optimum depth beneath the surface of the sea at which contemporaneous dolomitization proceeds.

A similar change is also apparent in the zones above the *Caninia*-oolite, in which contemporaneous dolomitization occurs at intervals in the southern outcrops but not in the anticline to the north. In these zones, however, other lithological changes become noticeable, for the entirely non-oolitic upper *Syringothyris*-subzone, the dark gasteropod-limestones of the lower *Seminula*-subzone, and the light oolite at the base of the upper *Seminula*-subzone are represented by dark, partly oolitic limestones in the northern part of the anticline. As a result of these changes the upper zones of the South Crop tend to assume the development which characterises the North Crop, which lies some distance north of the anticline. At the same time, the unconformity which has been already described in the case of the North Crop‡ begins to manifest itself at the base of the dark oolitic group of the South Crop.

The gradual development of the unconformity may actually

* 'Summary of Progress' for 1905, p. 48, *Mem. Geol. Surv.*

† A. Vaughan, in *Quart. Journ. Geol. Soc.*, vol. lxi, pp. 193 and 221.

‡ 'Summary of Progress' for 1902, p. 43; *ib.* for 1904, p. 44; *ib.* for 1905, pp. 46, 47, *Mems. Geol. Surv.*

be traced in some extensive quarries near Carew Newton and West Williamston. South of Carew Newton and throughout the southern limb of the anticline the *Caninia*-oolite is followed by a thin group of grey shales and compact or rubbly limestones, in which the only fossils that have been found, near Pembroke Dock, are entomostraca, *Spirorbis*, a lamellibranch and plant-fragments, an association pointing clearly to shallow-water conditions. This group passes up rapidly into the normal facies of the upper *Syringothyris*-subzone, of which it is really a peculiar basement-bed. But north-west of Carew Newton rubbly concretionary limestones are very conspicuous, and include, in the lower part, lumps of oolite resembling, though somewhat darker than, the *Caninia*-oolite, upon which they rest. Dr. Strahan, during a visit, suggested a derivation from slightly older beds for these lumps, a view which was afterwards confirmed by the discovery further north of evidence of an unconformity at this horizon. In the quarries nearest Carew Newton the *Caninia*-oolite continues solid to the top, but in others, 200 yards to the north-west, is penetrated to a depth of about 8 feet by irregular pipes filled with shale continuous with the matrix of the rubbly limestone above. They closely resemble those of recent origin, such as occur in the Yorkshire 'clints,'* and presumably were formed under subaerial conditions during a period of emergence following the deposition of the *Caninia*-oolite. They agree exactly with the pipes in the limestone beneath the conglomerate at Pendine.†

During the succeeding subsidence the pipes were filled with the calcareous mud which was first deposited and which enclosed also the debris lying on the surface. Northwards, they are constantly in evidence immediately beneath the rubble-bed, and the last exposure south of the Cresswell River shows that at the same time the limestone they penetrate begins to disappear. For in the northern part of Point Quarry the piped limestone has not the oolitic character of the top of the *Caninia*-oolite, but resembles the lower part of that rock, as though the upper portion, which is constantly oolitic in the Bristol-South Wales area, had been overstepped. That this explanation is correct is shown by the fact that the disappearance of the oolite is concurrent with the independent evidence of emergence afforded by the piping.

The facts leave little room to doubt that the unconformity of which the commencement in the West Williamston quarries is thus evidenced, develops northwards to the condition observable along the North Crop; presumably it is due to the same oscillation of the sea-bottom. In the quarries we get the data for determining the exact age of that movement, and find that subsidence recommenced at the beginning of the upper *Syringothyris*-subzone.

* *Proc. Yorks. Geol. Soc.*, vol. xv, pl. xxxvi.

† 'Summary of Progress' for 1904, p. 44, *Mem. Geol. Surv.*

The conditions which led to the deposition of the *Caninia*-oolite and the shallowing or upheaval which succeeded, prevailed generally over the South-West of England and Wales, a fact which suggests the top of the oolite as a natural horizon at which to subdivide the Avonian. It is interesting, therefore, to note that the separation of the latter into Kidwellian and Clevedonian is made by Dr. Vaughan, on purely palæontological grounds, at a horizon near, but slightly higher than, that of the unconformity.

### *Millstone Grit Series.*

The three divisions which have been found to hold good in Eastern Pembrokeshire can be recognized in the ground surveyed this year, but to the south of Haverfordwest certain changes gradually appear. Between Millin and Haroldston the thickness of the Basal Grit is less than it was some miles to the east. Near the Haroldston limestone-quarry only two or three thin beds of quartzite with interbedded soft black shales are present. From the general character of the beds and the abundance of Goniatites in one of the shale-bands it is most probable that the section here corresponds to the upper part only of the Basal Grit as exposed near Templeton and to the east. The lower beds have, therefore, been overlapped in the intervening ground. The Middle Shale subdivision is well exposed along Millin Pill and along the banks of the Eastern and the Western Cleddau. It consists as usual of grey shales and mudstones, with sandstones generally of an even-bedded flaggy type. In passing westward the sandstones become relatively more important, seemingly at the expense of the shales and mudstones. The Farewell Rock presents to a certain extent its usual characters but becomes of considerable thickness to the south of Haverfordwest. Near Boulston it contains some beds of pebbly sandstone near the base, such as have not been noticed in East Pembrokeshire.

### *Coal-measures.*

The coalfield of Landshipping and Martletwy is traversed in a west-south-westerly direction by an important fault, which ranges from Martletwy Wood to a point a short distance south of the Landshipping Quay. This fault passes close to the Landshipping Old Mill (after which it may be called) and follows the Landshipping Valley for about a mile, leaving it about half a mile east of the quay. It is convenient to consider separately the areas to the north and to the south of the fault.

The coals in the north part have been worked for generations, and some of the upper veins must have been fairly well-proved, though from various causes information is difficult to obtain nowadays. The veins to which names have been given

in the neighbourhood of Landshipping occur in descending order as follows:—

**Rock Vein.**
**Slate Vein (sometimes known as the Tumbling Vein).**
**Low Vein (of Timber Vein Series).**
**Big, High, or Timber Vein.**
**Little Vein.**
**Stinkard Vein.**

The principal vein is the Big, High, or Timber Vein, which corresponds to the Timber Vein of Jeffreston and Bonville's Court. The outcrop is made evident as a rule by the long narrow trenches which have been dug along it, and by the extensive collapse of the ground due to the thickness of the coal and the softness of the shale-roof. The Timber Vein has been worked chiefly from the Westmeadow Colliery, where it was found at a depth of about 80 yards, and the Garden Pit (65 yards) near Landshipping Quay. Work in this district was paralysed by a disaster at the latter pit on the 2nd of February, 1844. The men were working somewhere under the middle of the river (the exact position is not known) when the water broke in; they were all drowned, and the workings filled. Very little work has been done since that time. At the Westmeadow Colliery, which was re-started some years later, the fear of encountering old flooded workings to the south stopped work in that direction. The extent of the Timber Vein to the east is not known; the trench-like crop-workings end suddenly 200 yards south-east of Middle Hill Farm, and no information regarding the vein has been obtained over the area east of a line drawn from that point towards Millar's Park. It may be faulted out, but there is little evidence of such a fault on the surface.

Of the Slate Vein very little is known; it was said to have been met with about half-way down the Westmeadow shaft, and it is probably the vein that has been worked along the crop 200 yards north of the shaft. The Rock Vein, so-called from having a massive quartzitic sandstone above it, occupies, as a shallow syncline, a small area on both sides of the western end of the Landshipping Valley. The syncline is also shown by the workings in the Big Vein underneath. To judge from the numerous holes put down through the sandstone to the Rock Vein in Backs Wood, and to the south, the coal must have been nearly all removed. None of these workings are remembered by the inhabitants.

A much-disturbed vein of coal under a massive sandstone is exposed in an old quarry 100 yards east of the Garden Pit, and about 65 to 70 yards above the Big Vein as proved in that pit; this is probably the Rock Vein. Among the lower veins the Stinkard alone appears to have been worked to any extent. It obtained its name from the amount of sulphur it contained, probably in the form of iron-pyrites. The outcrop is frequently marked by abundance of ferruginous water, which

seems to be more characteristic of this than of any other of the lower veins. It is probably this vein that has been worked along the crop between Rigan Pill and Landshipping Ferry.

Signs of other and lower veins appear in the estuary section north-east of Rigan Pill. Some of these possibly correspond with the Lower Level (or Bonville's Court Vein, as it is sometimes called in this district), Kilgetty and other veins of East Pembrokeshire, but they are all thin and worthless. One of these has been dug at the crop south of Vogar; it consisted only of 6 to 8 inches of smut. Two or more of these lower veins have been worked in the north end of the Martletwy Wood, and in the field to the north-east.

The identification of the veins on the south of the Old Mill Fault presents considerable difficulties, because little work has been done on them, and that only along and near the outcrops. It seems generally agreed that the Timber Vein series occurs there, though that vein itself has not been recognised with certainty.

An important attempt to prove this area was made when the Lady Berwick Pit (known also as the Mill Pit) was put down on the south side of the valley near the Old Mill. Unfortunately, the site chosen was close to, if not actually upon, the Old Mill Fault mentioned above; it is also fairly certain that the measures at the surface there are considerably below the Timber Vein series. Several veins were passed through in the shaft, but the greater number of them were thin and valueless. A two-foot vein at a depth of 12 yards was supposed to be the Stinkard, and an eighteen-inch vein at 27 yards is probably the Stud Vein, which has been largely worked along Engine Bottom on the south side of the Martletwy-Landshipping Valley. So far as is known, it has not been recognised elsewhere. A vein of culmy coal, 4 ft. 3 in. thick, and at 52 yards depth, has been identified as the Timber Vein which normally lies some distance above the Stinkard Vein. These two identifications, if correct, are not impossible to reconcile, for the shaft was on or near the Old Mill Fault, and the faults of this neighbourhood as displayed in the estuary section are all overthrusts from the south. The strata in the pit are known to have been greatly disturbed down to a depth of 30 or 40 yards, and it is quite possible that the shaft passed through the fault.

Another attempt to prove the veins in this area was made in the Westfields Slant, 170 yards north-east of the farm, by Mr. John Roberts, to whom we are indebted for much of the information concerning this district. This slant was put in on the first vein proved, without regard to thickness or quality. The ground was rather disturbed or 'tumbly,' and it is supposed that the workings passed from one vein to another. The veins varied from 1 ft. 6 in. to 3 ft. 6 in. in thickness, and were called by the workmen the Low and Tumbling Veins. As these are above the Timber Vein a trial-pit was put down on the crop of what was supposed to be that vein. Coal was

found, but it was 'not healthy.' Quite recently a hole has been dug by a farmer 300 yards north of Westfields Farm on the crop of the same vein; it is there about 5 feet thick, but the lower 3 feet are culmy and much squeezed with some thrusting. There are signs of two lower veins having been worked at the crop in the immediate neighbourhood, and near Buck Velge a higher vein has been dug, which probably underlies a quartzitic sandstone. If the above group of veins is correctly referred to the Timber Vein and its associates, the one near Buck Velge might perhaps correspond to the Rock Vein. The lithological character of the sandstone above it corresponds better with that of the Rock Vein than any other sandstone seen on the south of the Old Mill Fault. The crops of the above veins cannot be traced far in either direction; on the west they run into the fault of the Landshipping Valley, while on the east they are lost in some much broken ground around Weston. How highly disturbed this region is, is shown by the stream-section, south of Martletwy Church. There are many crops near Weston along which coal has been 'smutted,' but none run far; they may be repetition by thrusting of one vein or a group of veins. A hole dug on a crop 300 yards south-east of Landshipping Old Mill showed a thickness of 8 feet of culmy coal dipping to the north at 65°. The great thickness suggests the Timber Vein, but nothing further is known of the seam.

The part of the coalfield which lies south of the Saundersfoot, Moreton and Broadmoor productive belt has been examined with an almost negative result. The Stammers Veins, which we believe to be older than those of the productive belt,* have been worked through Road Wood, and nearly as far as Broad Fields, but have not been identified further west on the same outcrop. A cutting on the railway west of Knightston Farm shows one or two thin coals, and close by there are quarries in sandstone which resembles those in the lower part of the Coal-measures. Another cutting, one mile further north and near North Vatson, traverses shales with thin coals and a sandstone, which is supposed to be the Catshole Rock. In all the cuttings, however, the strata are sharply folded, and no more can be said of the tract south of the productive belt than that it is occupied in the northern part by Coal-measures with thin seams of little or no value, and in the southern part by contorted shales with some sandstones, which probably belong to the Millstone Grit. To the east lies the coast-section showing the various anticlines and overthrusts described in the SUMMARY OF PROGRESS for 1905, p. 63, and to the west of it the limestone comes to the surface in the anticline of Ivy Town, and in what appears to be another anticline near Redberth. The course of these folds and thrusts across the tract in question and the boundary-line between Coal-measures and Millstone can be only conjectured.

Dr. Strah

* 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), p. 62.

### *Folds, Faults, and Disturbances in the Carboniferous Tract.*

Mr. Jones. Several faults run along the valley of the Eastern Cleddau from near Llawhaden to Slebech. Near the latter place the Carboniferous rocks are displaced a quarter of a mile to the north by an east-and-west fault.

The Old Mill Fault between Martletwy and Landshipping, and the disturbance near Weston, mentioned in the description of the Coal-measures, probably form part of the Red Roses Disturbance alluded to in previous Summaries. This preserves its west-south-westerly direction, but increases in effect westward, and gives off several important faults between Templeton and Martletwy. In addition to the disturbance from the east-north-east, a southerly set enters the region from a little south of east. They tend to meet near Landshipping, where the rocks exposed along the estuary are greatly disturbed; the structures are difficult to account for, though they resemble those which usually accompany the Red Roses Disturbance. Farther to the south they show the characteristic overfolds and overthrusts of the southern type, which increase in frequency and intensity southward. At Landshipping, therefore, it is difficult to disentangle the two sets of disturbances. As the section along the estuary shows the gradual incoming of the disturbances in passing from north to south it merits a brief description.

The section along the Eastern Cleddau begins in the Lower Llandovery Mudstones south of Blackpool; these dip south at high angles, and are followed by the Old Red Sandstone with a somewhat similar dip. The Lower Carboniferous Rocks which succeed near Slebech are seen on the west side of the river, and have a much gentler dip, which remains fairly steady in the Middle Shales and Farewell Rock for about three-quarters of a mile to the south. The next part of the section is best exposed on the east side of the river, and begins at Layers Pill with the lower beds of the Coal-measures. Two overthrusts from the south can be seen about 250 yards south of the Pill; they are probably branches of the Red Roses Disturbance. From this point to Rigan Pill, about half a mile to the south, the Coal-measures have been affected by one or two shallow anticlines and synclines, and a few small normal faults and overthrusts from the south. The section on the east side is then interrupted for nearly a mile, but this gap is partly filled up by that on the opposite side of the river. The Coal-measures there show repeated small overthrusts and overfolds from the south, which increase in frequency and intensity southward towards Picton Point. Near the latter place the effect of the structures can be readily traced by means of a well-marked band of carbonaceous shale, crammed with irregular nodules of ironstone. This band makes its appearance again and again for about 120 yards north of the point. The Eastern Cleddau is here joined by the Western Cleddau

to form the Daucleddau. On the east side of the Daucleddau and on the north side of the small bay, where the stream enters at Landshipping, some highly disturbed strata are exposed, and a carbonaceous band with ironstone-nodules, probably identical with the one at Picton Point, is prominent. On the south side of the Landshipping Bay, near the quay, the section recommences, and is continued with one or two small gaps for about half a mile. For the first two hundred and fifty yards the rocks are amazingly contorted, overthrust, and overfolded, all the structures indicating a pressure from the south. At the end of this space a small stream enters, and immediately to the north a fault with a clean-cut plane lying almost horizontally is displayed. Its effect is not known, but it is probably an overthrust from the south; the shales underneath are highly contorted and slickensided, and the highly disturbed nature of the beds to the north of this point suggests that they may have formed the floor of this overthrust. For the next two hundred yards or so the strata are not so contorted, though overthrusts are still frequent. The structures then become more regular, and can be assigned definitely to the southern set of disturbances. Several folds, in which the northern limb in steep, vertical, or even inverted, while the southern limb dips more gently, succeed one another rapidly, and are usually accompanied by faults of unknown magnitude which have every appearance of being overthrusts from the south. These are followed by several symmetrical folds in sandy shales and mudstones, with thin flaggy sandstones; this state of things continues for nearly a quarter of a mile, where the section on the east side ends for a space. On the opposite side the section is resumed about half a mile north of Blacktar and continues without interruption as far as that place. The first strata visible appear to be the continuation of those last seen on the opposite side. Passing southward, they end abruptly against a fault on the north side of a monoclinal fold, and for the next half-mile the beds are thrown into a rapid succession of such folds, while the overthrusts are more violent and the squeezing and contortion of the softer strata is more pronounced.

Although in this section inversion obtains at intervals for considerable distances, yet the resultant effect, apart from the overthrusts, would be an ascending series to the south. From the presence of well-bedded quartzitic sandstones and quartzites, as well as from other lithological characters, it is fairly safe to assign all this part of the section to the Millstone Grit Series, and probably to the upper part of it. As it follows strata which are of Coal-measure age, a fault must intervene, but although faults are sufficiently numerous it is almost impossible to decide which are the most important. Exactly in the line of strike of the last strata visible, at Blacktar, but on the opposite side of the river, the section is once more resumed and is complete for nearly a quarter of a mile. The rocks are similar to those at Blacktar; in the first

part of the section they are not much disturbed, but there is abundant evidence of shearing movement parallel to the bedding-planes. About the middle of the section a belt of disturbance commences suddenly and reaches, towards the south end of the section, an intensity not met with anywhere to the north. For a space of about fifty yards the softer strata are sheared to a schistose mass in which are embedded angular lumps of quartzite, sandstone and ironstone, forming a typical 'crush-rock.' At one part in this crushed belt occur three huge boulders of the white quartzite of the basal part of the Millstone Grit Series. One of these is cylinder-shaped and is completely surrounded by a sheared mass of shale. Although extremely tough, it has the appearance, at any rate in parts, of having been crushed and re-cemented. In the bank, a few yards to the south, is a bed of quartzite associated with black shales crowded with Goniatites and other marine fossils similar to those which occur at Templeton and other places in the upper portion of the Basal Grit. The shales have a distinct cleavage, which makes its appearance in the section for the first time. This completes the continuous section, but scattered exposures of the succeeding strata occur, partly in quarries, and partly along the foreshore. About fifty yards south of the fossiliferous shales and quartzite is the north Langum Ferry limestone-quarry. The rock is a light-grey oolite veined through and through with spar, while certain bands show how intense has been the shearing in the fact that the oolite-grains have been drawn out into streaks. The limestone dips to the south and belongs to the lower part of the *Dibunophyllum*-zone. The southerly dip proves that it has been thrust over the quartzite to the north. The south limestone-quarry, in similar beds and with a similar dip, is separated from the other by about thirty yards, but in this short space there is probably an overthrust, for a mass of quartzite and crushed shales is exposed between the two quarries. The effects of shearing are more pronounced in the south quarry and a considerable thickness of beds is affected. Still farther south, a few scattered exposures of dark-blue sheared limestone are visible, and then, after a small gap, olive-green and red mudstones with bands of coarse pebbly sandstone. The dip is still to the south, but as these strata are of Lower Old Red Sandstone age, it is clear that they in turn have been thrust over the Carboniferous Limestone just as the Limestone was thrust over the Millstone Grit and the Millstone Grit over the Coal-measures. As described in the coast-section from Amroth to Tenby,* the persistent southerly dip on the south side of the coalfield is thus as persistently counteracted by the overthrusting from the south. The Old Red Sandstone exposed at the point south of the Ferry House, at Langum Ferry, shows an incipient cleavage which has the same strike as the overthrusts and dips steeply to the south.

* 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), pp. 56-65.

The Ritec fault, one of the series of pre-Triassic, east-and-west disturbances, which has been mentioned in previous Summaries of Progress, has now been traced continuously from the coast of Carmarthen Bay at Tenby, to the shore of Milford Haven at Pembroke Dock. Along that part of its course which lies between Tenby and Carew Cheriton, it throws Carboniferous Limestone of low horizon on the south against Millstone Grit shales on the north. Then crossing the limestone obliquely, it brings the upper part of that formation against Old Red Sandstone on the south at Carew Cheriton and onward. As it follows one horizon of the limestone on the one side but gradually introduces lower horizons of Old Red Sandstone on the other its throw increases westward until, where it enters Milford Haven, it is still bordered on the north by the top of the limestone (the *Dibunophyllum*-zone) but on the south by a part of the Lower Old Red Sandstone, which lies far below the Ridgeway Conglomerate. Its throw must be at least 2,000 feet and may be as much as 4,000 feet, though it produces little internal disturbance in the adjacent rocks. Mr Dixon

## PLEISTOCENE.

### *Raised Beach.*

At various places along the arms of Milford Haven a rock-platform separates the present shore from the steep banks of the estuary. On one side it terminates at about high-water mark; on the other, it rises to several feet above that level. In places it is overlain immediately by angular 'head,' but generally by a deposit of buff or grey clay containing charcoal-fragments and more or less well-rounded stones, and in places accompanied by shingle. This clay in its turn underlies angular head, it never rises more than a foot or so in the low cliff separating foreshore from platform, and its greatest known thickness is 4 feet. Mr. Dixo

Although it differs greatly from the head above in containing many fragments of vein-quartz and other rocks, it is probable, from its containing charcoal-fragments and from its stones not being ice-scratched, so far as is known, that it is not glacial drift. Its mode of occurrence on a rock-platform suggests that it is a raised estuarine shore-deposit. It differs, however, from the adjoining modern shingle in containing many rocks of distant origin, but the latter, which have been examined by Mr. O. T. Jones, may have been derived from higher reaches of the river. It would probably compare more closely with the off-shore tidal mud with stones than with the shingle.

In this district the platform has nowhere been found in clear association with glacial deposits, but in the estuaries of the Cork district a similar terrace, with or without a covering of raised shore-deposit which in one place is compared with an alluvial wash, has been proved to be pre-glacial like the raised

beach on the neighbouring coast.* It is probable, therefore, that the platforms of Milford Haven form the estuarine counterpart of the pre-glacial terrace which is known to exist in the sea-cliffs of the neighbourhood.

### *Glacial.*

In the neighbourhood of Castelldwyran, Llanfallteg, and Clynderwen, large masses of gravelly drift cap all the elevations and extend some way down into the valleys. The gravels contain flints, fragments of Old Red Sandstone and many rocks quite foreign to the district in which they now occur. There is almost a complete absence of true boulder-clay such as was present in Carmarthenshire, all the deposits tending to be fluviatile in character. Scattered over the driftless areas and lying in the bottom of valleys are many large boulders usually much larger than any observed in the gravels. Those between Henllan Amgoed and the Eastern Cleddau are almost all of one type, which the microscope has shown to be an ophitic diabase with partially absorbed felspar-phenocrysts. These large felspars occur generally without any well-defined boundary, they weather pure white and are conspicuous as white spots on the surfaces of the rock. The source of these boulder lies in the Prescelly Mountains, along which sill-like masses, of a character identical with the boulders, run from Rosebush to Crymmych, forming conspicuous crags, especially at Carn Meini, where the large white felspars are particularly abundant. The direction of transport varied from S.E. to S.S.E.

To the west of the Eastern Cleddau there appears a different set of boulders, which consists of rhyolites, ashes, quartzites, diabases without white spots, etc. A granite boulder occurs at Spittal, and at Clarbeston a diabase referable to the St. David's Head mass. These boulders were derived from the igneous rocks, etc., of North Pembrokeshire, as well as from those of Trefgarn and Ambleston, and must have travelled in a direction generally parallel to, but slightly more east than, the course followed by the Prescelly erratics. In some coarse gravels which fringe the valley of the Western Cleddau from Letterston to Haverfordwest there occur large quantities of a blue ophitic diabase, very like the Stumble Head rock in general appearance.

Very little unequivocal boulder-clay has been met with in the neighbourhood of Narberth and Haverfordwest; and much of the stony clay in the low ground may be nothing more than 'wash.' But gravel and sand of undoubtedly glacial origin occur in the form of outliers, generally on the low divides between valleys. Gravel is abundant at Clynderwen and Egremont, and in the form of small patches near Bletherston and

* H. B. Muff and W. B. Wright in 'The Country Around Cork and Cork Harbour,' pp. 39, 90, 91, *Mem. Geol. Surv. Ireland.*

Clarbeston. It consists chiefly of local material, but with an admixture of far-travelled pebbles, including flints.

There are a few small patches of boulder-clay in the Narberth district. Some of them contain abundance of igneous boulders. Mr. Jones.

Along the Cleddau to the south of Haverfordwest the drift is of a different character. It consists of well-rounded pebbles and boulders of a variety of igneous rocks; the matrix is loamy or gravelly. This gravelly drift, which occurs as a rule on the higher ground, is associated with some boulder-clay which occurs in the valleys and in hollows.

No glacial drift has been recognized between Saundersfoot and Tenby, nor in the direction of Redberth, but near the last-named place two boulders of an igneous rock, not yet determined, have been noted. They must each weigh little short of a ton, and they lie in the fields far from any railway or road. There are a few boulders of quartzite also in the same neighbourhood, which no doubt have been glacially transported. Dr. Strahan.

ECONOMICS.

In the Ordovician and Silurian tracts building-stone is obtained from the Llandilo Limestone of Bletherston, the *D. bifidus*-ashes, and the Llandovery Sandstone of Wiston and Hareshead. Road-metal is got from the ashes in Clarbeston Parish, from the Llandilo and Bala Limestones, and from the Llandovery Sandstones of Hareshead, Vaynor, Robeston Wathen, and Holgan. Much of the road-metal used to the north of Haverfordwest comes from the andesitic rocks which are quarried east of Trefgarn Village.

The Bala Limestone of Robeston Wathen and Grondre was once extensively burnt, chiefly for agricultural purposes. The Grondre Quarry was last worked about twenty-five years ago. Lime is now obtained extensively from the Carboniferous Limestone.

The Carboniferous Limestone was formerly burnt at Milton, Hanton, and Haroldston St. Issels. At West Williamston a large quantity of limestone has been worked along the shore of the estuary in a range of large quarries which communicate with the estuary by artificial creeks. Much of it went to the neighbourhood of Haverfordwest and along the Cardiganshire coast for agricultural purposes. No lime is now burnt, but some of the quarries supply road-stone for places along Milford Haven. There is much tidal mud near the quarries, but no attempt has been made to make cement.

Water is obtained for Pembroke Dock from large issues from the limestone at Milton. In the Narberth and Haverfordwest districts much of the supply is obtained from dip-wells. The drift-gravels of the regions around Llanfallteg and Clynderwen yield a plentiful supply. The best springs, however, are those which rise at the junction of the upper and lower divisions of the Old Red Sandstone in the Pembroke district.

## II.—PETROGRAPHICAL WORK.

Dr. Flett reports that during the year the work of the Petrographer has consisted mainly in preparing chapters and descriptive notes for Geological Survey memoirs. In this he has received assistance from Mr. George Barrow, Mr. H. H. Thomas, Mr. E. B. Bailey, Mr. H. B. Muff, and Mr. G. W. Grabham. Dr. Teall and Mr. Harker have also made contributions to some of the memoirs in hand. The following memoirs have been prepared for publication during the year:—Land's End and St. Ives (351 and 358), Plymouth (348), Falmouth and Camborne (344), Mevagissey (353), Beauly (83), Kilmartin (36), Dalmally (53), Loch Lomond (38), Islay (19 and 27), Small Isles (60), Glenelg (71), Midlothian (32), East Lothian (33), Carmarthen (229), Hungerford (267), Ivybridge (349), and Swansea (247).

## III.—CHEMICAL WORK.

The following rock analyses have been executed in the Survey's Laboratory during the year 1906 by Dr. W. Pollard, and Mr. E. G. Radley. For convenience of reference and comparison the results have been arranged according to the areas from which the specimens are derived. Brief descriptions are given of the rocks and their mode of occurrence, but fuller details will appear in the memoirs on these respective areas, which are now in hand and will shortly be published.

*Analyses of rocks from Sheet 93, Scotland (Garve), prepared for Dr. J. S. Flett.*

11789. At the hut ⅛ mile E. by N. of Leaba Bhaltair, Ross. *Granite-gneiss* of the Carn Chuinneag complex.

11790. 785 yards slightly E. of N. of Carn Dubh, Ross. *Amphibolite.*

11792. Middle Glen, S. side of Glen Diebidale, Ross. *Amphibolite.*

The first of these represents the normal acid portion of the augen gneiss; the others are marginal basic facies of the same mass, and were probably originally augite diorites, though now converted into amphibolites.

| —— | 11789. | 11790. | 11792. |
|---|---|---|---|
| $SiO_2$ | 73·19 | 54·51 | 52·84 |
| $TiO_2$ | ·27 | 1·74 | 2·19 |
| $Al_2O_3$ | 12·65 | 12·26 | 14·06 |
| $Fe_2O_3$ | 1·04 | 1·64 | 1·73 |
| FeO | 1·53 | 7·60 | 8·38 |
| MnO | ·08 | ·32 | ·25 |
| (CoNi)O | Nt. Fd. | ·03 | ·05 |
| CaO | ·55 | 8·80 | 8·72 |
| BaO | Nt. Fd. | Nt. Fd. | Nt. Fd. |
| MgO | ·39 | 6·89 | 5·55 |
| $K_2O$ | 5·08 | 1·85 | 1·74 |
| $Na_2O$ | 4·45 | 2·37 | 2·90 |
| $Li_2O$ | Trace. | Trace. | Trace. |
| $H_2O$ at 105° C. | ·09 | ·04 | ·08 |
| $H_2O$ above 105° C. | ·38 | ·94 | 1·15 |
| $P_2O_5$ | ·24 | ·78 | ·29 |
| F | Nt. Fd. | — | — |
| $FeS_2$ | ·17 | ·20 | ·14 |
| $CO_2$ | — | ·36 | — |
| Cl | — | ? Trace. | — |
| —— | 100·02 | 100·33 | 100·07 |
| Anal. | E. G. Radley. | W. Pollard. | E. G. Radley. |

11801. Between the two thrust planes, on Abhuinn Salachie, 1 mile S.E. of Glencalvie Lodge, Ross.

*Garnetiferous mica schist.*

11797. Abhuinn Salachie, 1 mile S.E. of Glencalvie Lodge, Ross.

*Garnetiferous biotite hornfels.*

12682. On hill ¾ mile S.W. of Glencalvie Lodge, R. Carron, Ross-shire.

*Garnetiferous muscovite biotite schist.*

These are analyses of the pelitic sediments of the Moine series, in three different stages of metamorphism.

11798. On hill ¾ mile S.W. of Glencalire Lodge, R. Carron, Ross-shire.

*Garnetiferous zoisite hornblende schist.*

Occurs with 12682, and represents a calcareous pelitic sediment of the Moine series, which has been metamorphosed.

| —— | 11801. | 11797. | 12682. | 11798. |
|---|---|---|---|---|
| $SiO_2$ | 64·98 | 63·74 | 67·77 | 62·55 |
| $TiO_2$ | ·89 | 1·11 | 1·04 | ·79 |
| $ZrO_2$ | — | — | Trace. | — |
| $Al_2O_3$ | 11·42 | 17·23 | 16·42 | 15·75 |
| $Fe_2O_3$ | 7·21 | ·94 | 1·37 | 1·56 |
| FeO | 5·41 | 5·03 | 3·68 | 3·26 |
| MnO | ·11 | ·24 | ·33 | ·28 |
| (CoNi)O | Trace. | ·04 | ·04 | ·04 |
| CaO | 1·26 | 1·60 | 1·23 | 9·39 |
| SrO | — | — | Trace. | Trace. |
| BaO | Nt. Fd. | Nt. Fd. | ·06 | ·05 |
| MgO | 1·71 | 1·70 | 1·50 | 2·88 |
| $K_2O$ | 3·95 | 3·55 | 3·58 | 1·54 |
| $Na_2O$ | 1·72 | 2·97 | 2·28 | ·93 |
| $Li_2O$ | Trace. | ? Trace. | ? Trace. | Trace. |
| $H_2O$ 105° C. | 1·09 | ·15 | ·04 | ·15 |
| $H_2O$ above 105° C. | ·04 | ·98 | ·74 | ·64 |
| $P_2O_5$ | ·14 | ·24 | ·15 | ·30 |
| S | — | — | Nt. Fd. | Nt. Fd. |
| $CO_2$ | — | — | Nt. Fd. | Trace. |
| Cl | — | — | Nt. Fd. | — |
| $Fe_7S_8$ | ·07 | — | — | — |
| $FeS_2$ | ·13 | ·38 | — | — |
| —— | 100·13 | 99·84 | 100·23 | 100·11 |
| Anal. | E. G. Radley. | E. G. Radley. | W. Pollard. | W. Pollard. |

11796. N.W. shoulder of Carn Chuinneag, Ross-shire, ½ mile south of Diebidale Lodge.

This is a dark nodular *mica schist* containing large garnets (one or two inches in diameter) and streaks of magnetite, some of which carry a small percentage of cassiterite. Under the microscope its constituents prove to be principally orthoclase, albite, quartz, green and brown biotite, chlorite, carbonates and iron oxides.

11791. Burn 1,306 yards S.E. of Dunan Liath, Ross.

Dark green *peridotite*, occurring as a sill or dyke in the schists, and consisting of grains of olivine (partly serpentinised) in a matrix of scaly chlorite, probably after original pyroxene.

12680. Above the rock pinnacle on the face of the hill S. side of Glen Diebidale, Ross, rather more than 1 mile above the old Lodge.

*Amphibolite.*

A much sheared and well foliated dyke traversing the augen gneiss; evidently originally a dolerite.

| —— | 11796. | 11791. | 12680. |
|---|---|---|---|
| $SiO_2$ | 54·89 | 41·01 | 47·36 |
| $TiO_2$ | ·38 | ·66 | 2·02 |
| $Al_2O_3$ | 16·54 | 5·00 | 12·47 |
| $Fe_2O_3$ | 1·85 | 5·52 | 2·64 |
| FeO | 12·30 | 8·66 | 10·03 |
| MnO | ·84 | ·47 | ·14 |
| (CoNi)O | ·02 | CoO ·05<br>NiO ·17 | ·07 |
| CaO | 1·08 | 4·43 | 9·70 |
| BaO | Nt. Fd. | ? Trace. | Nt. Fd. |
| MgO | 1·52 | 26·92 | 6·97 |
| $K_2O$ | 2·35 | ·25 | 1·08 |
| $Na_2O$ | 5·39 | ·98 | 2·50 |
| $Li_2O$ | Trace. | Nt. Fd. | Trace. |
| $H_2O$ 105° C. | ·11 | ·43 | ·10 |
| $H_2O$ above 105° C. | 2·29 | 4·95 | 1·59 |
| S | ·02 | Nt. Fd. | Nt. Fd. |
| $P_2O_5$ | ·07 | ·10 | ·30 |
| $CO_2$ | ·42 | ·76 | 3·21 |
| $Cr_2O_3$ | — | ·14 | — |
| $V_2O_3$ | — | ·03 | — |
| CuO | — | Trace. | — |
| Total | 100·07 | 100·53 | 100·18 |
| Anal. | W. Pollard. | W. Pollard. | E. G. Radley. |

*Rocks from the Plymouth District. Sheet* 348. *Analysed for Dr. J. S. Flett.*

E4329. Crag in field near Criffel Mill, ½ mile S.W. of Molenick, Cornwall.

*Hornblende peridotite.*

E4770. Crag overlooking valley, 200 yards N. of viaduct, S.W. of Cartuther, Menheniot, Cornwall.

*Proterobase.*

E4763. Quarry on W. side of River Lynher, opposite Grove, Landrake, Cornwall.

*Proterobase.*

E4947. Enclosed Quarry, E. of Workhouse, Devonport.

Porphyritic *spilite*, with phenocrysts of albite in a decomposed matrix full of calcite and chlorite.

| —— | E4329. | E4770. | E4763. | E4947. |
|---|---|---|---|---|
| $SiO_2$ | 39·14 | 47·19 | 42·88 | 40·55 |
| $TiO_2$ | 1·66 | 2·09 | 3·68 | 2·95 |
| $Al_2O_3$ | 7·59 | 13·96 | 14·31 | 16·65 |
| $Fe_2O_3$ | 5·26 | 3·39 | 4·70 | 1·13 |
| FeO | 8·76 | 9·01 | 9·44 | 9·46 |
| MnO | ·56 | ·47 | ·32 | ·20 |
| (CoNi)O | ·11 | ·04 | ·07 | ·07 |
| CaO | 5·91 | 8·08 | 10·90 | 6·06 |
| MgO | 22·78 | 7·10 | 5·67 | 5·20 |
| $K_2O$ | 1·09 | ·70 | 1·92 | ·27 |
| $Na_2O$ | ·60 | 4·50 | 2·52 | 4·76 |
| $Li_2O$ | Trace. | Trace. | Trace. | ? Trace. |
| $H_2O$ 105° C. | ·56 | ·12 | ·25 | ·27 |
| $H_2O$ above 105° C. | 6·30 | 2·56 | 2·52 | 3·89 |
| $P_2O_5$ | ·38 | ·56 | ·54 | ·73 |
| BaO | Nt. Fd. | ·06 | Nt. Fd. | Nt. Fd. |
| $FeS_2$ | — | ·11 | — | — |
| Cl | — | ? Trace. | — | Nt. Fd. |
| $CO_2$ | — | ·79 | ·13 | 7·85 |
| S | — | — | ·22 | ·10 |
| Total | 100·70 | 100·73 | 100·07 | 100·14 |
| Anal. | E. G. Radley. | W. Pollard. | E. G. Radley. | E. G. Radley |

*Analyses of three Rocks from Sheet* 45, *Scotland.*

11817 is a dyke of *camptonite*, about three feet wide, traversing grey micaceous phyllites. These are baked at the contact and converted into dark vitreous *buchite*, with many small crystals of cordierite (11819). The unaltered phyllite at a distance of six feet from the dyke was also analysed (11833). The locality from which these specimens came is the north-east corner of Sailean Sligenach, west coast of Ardmucknish.

| —— | 11819. | 11833. | 11817. |
|---|---|---|---|
| $SiO_2$ | 58·63 | 62·01 | 42·22 |
| $TiO_2$ | 1·01 | 1·02 | 2·49 |
| $Al_2O_3$ | 18·59 | 17·78 | 10·62 |
| $Fe_2O_3$ | 1·93 | 1·25 | 4·74 |
| $Cr_2O_3$ | Undet. | Undet. | ·10 |
| $V_2O_3$ | Undet. | Undet. | ·05 |
| FeO | 6·46 | 6·63 | 6·18 |
| MnO | ·38 | ·49 | ·50 |
| (CoNi)O | ·03 | ·04 | ·05 |
| CaO | ·56 | ·42 | 14·80 |
| BaO | ·06 | ·05 | ·04 |
| SrO | Trace. | Trace. | Nt. Fd. |
| MgO | 2·62 | 2·04 | 8·68 |
| $K_2O$ | 2·01 | 3·43 | 1·41 |
| $Na_2O$ | 2·58 | 1·84 | 2·46 |
| $Li_2O$ | ? Trace. | Trace. | ? Trace. |
| $H_2O$ 105°C. | 1·38 | ·08 | ·50 |
| $H_2O$ above 105°C. | 4·45 | 3·02 | 1·16 |
| $P_2O_5$ | ·08 | ·11 | ·73 |
| $CO_2$ | Nt. Fd. | Nt. Fd. | 3·57 |
| S | Nt. Fd. | Nt. Fd. | ·12 |
| Total | 100·77 | 100·21 | 100·42 |

Anal. W. Pollard.

12453. Lowest pillow-lava on the west shore of the Tayvallich peninsula, 5-16ths mile north of the summit of An Aird, and 2¾ miles S.W. of Tayvallich, Argyll. (Sheet 28, Scot.)

This is a porphyritic igneous rock, composed of albite and oligoclase, quartz, chlorite, and carbonates, with iron oxides. It belongs to the same group as the rock from Devonport Workhouse quarry, of which an analysis is given above.

12710. Quarry at Corston Hill, Corston, Midlothian.

A *mugearite*. This analysis should be compared with that given of the type rock from Skye by Mr. Harker. (Tertiary Igneous Rocks of Skye, p. 263.)

| —— | 12453. | 12710. |
|---|---|---|
| $SiO_2$ | 51·31 | 49·29 |
| $TiO_2$ | 1·92 | 2·27 |
| $Al_2O_3$ | 12·67 | 16·66 |
| $Fe_2O_3$ | ·54 | 7·24 |
| FeO | 7·99 | 4·81 |
| MnO | ·45 | ·55 |
| (CoNi)O | ? Trace. | ·04 |
| CaO | 8·17 | 5·63 |
| BaO | Nt. Fd. | ? Trace. |
| MgO | 2·19 | 2·42 |
| $K_2O$ | ·54 | 1·86 |
| $Na_2O$ | 5·21 | 4·98 |
| $Li_2O$ | ? Trace. | Trace. |
| $H_2O$ 105°C. | ·04 | ·34 |
| $H_2O$ above 105°C. | 2·31 | 2·11 |
| $P_2O_5$ | ·90 | ·24 |
| $CO_2$ | 6·15 | 2·32 |
| $Fe_7S_8$ | ·17 | Nt. Fd. |
| $FeS_2$ | ·30 | |
| Cl | ? Trace. | ? Trace. |
| Total | 100·86 | 100·77 |
| Anal. | E. G. Radley. | W. Pollard. |

*Analysis of Pink Clay from Carbis, near Roche, Cornwall.*

(Lab. No. 246).

| | |
|---|---|
| $SiO_2$ | 46·25 |
| $TiO_2$ | ·08 |
| $Al_2O_3$ | 36·34 |
| $Fe_2O_3$ | 1·21 |
| FeO | ·50 |
| MnO | ·31 |
| CaO | ·27 |
| MgO | ·66 |
| $K_2O$ | 1·76 |
| $Na_2O$ | ·29 |
| $Li_2O$ | ·02 |
| $H_2O$ 105° C. | ·71 |
| $H_2O$ above 105° C. | 12·13 |
| $P_2O_5$ | ·04 |
| Total | 100·57 |

$Cr_2O_3$ and $V_2O_3$ not found. Trace of organic matter.

The cause of the colour is probably due to $Fe_2O_3$ finely divided. Samples of white clay mixed with (1) 1.0% $Fe_2O_3$, (2) 1.2% $Fe_2O_3$ and .4% $MnO_2$ show colour very nearly that of the clay. All these when ignited in platinum crucibles become white. When ignited, however, in porcelain in a muffle they remain somewhat pink, that with the manganese being least pink. It is possible the greater heat obtained in the platinum crucible would account for the complete bleaching.

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## IV.—PALÆONTOLOGICAL WORK.

Dr. Kitchin.

During the year, the resources of the palæontological department have been largely employed in dealing with the specimens, more than 8,000 in number, which have been added to the collections. Mr. J. Pringle collected upwards of 4,000 of these. Most of the additions relate to field-work now in progress, and the results of the examination of suites of specimens of this character will be embodied in the respective sheet memoirs. Dr. Ivor Thomas has been almost wholly engaged in examining and naming a large part of these materials which relate to the current work of the survey, but as in former years, many specimens have also been submitted to specialists who are not members of the staff. Thus, graptotites and trilobites from South Wales have been dealt with by Mrs. Shakespear and Mr. P. Lake, and brachiopods by Dr. C. A. Matley. Dr. W. Hind has examined Carboniferous lamellibranchs, and Dr. Traquair has also given assistance by naming fish-remains from the Carboniferous rocks of the Midland counties. Mr. Kidston has received further collections of coal-plants from South Wales and the Forest of Wyre, and continues the preparation of his memoir on the Carboniferous flora of this country.

The list of donations to the museum collection is published in the Annual Report for the year 1906. Amongst the more interesting additions may be noted a series of belemnites from the zones of *Belemnites lateralis* and *Belemnites brunsvicensis* of Speeton, presented by Mr. C. G. Danford. These specimens are split open in order to show the differences in the apical termination of the alveolar cavity in the two groups of belemnites typified by the above zonal forms.*

Dr. H. C. Male has provided a representative series of bones from the cave at East Clevedon, Somerset, while two fine

* C. G. Danford, "Notes on the Belemnites of the Speeton Clays." *Trans. Hull Geol. Soc.*, vol. v., part i., pp. 8, 9. 1906.

examples of *Prestwichia*, and a specimen showing the fructification of *Calamocladus equisetiformis* (Schloth.), from the Coal-measures north-west of Ilkeston, Derbyshire, are added through the generosity of Dr. L. Moysey.

Special attention may be drawn to the valuable collection of fossils from the Speeton series, acquired from Mr. C. G. Danford. This is, perhaps, the largest and most complete set of specimens from the Speeton section which has been collected with strict regard to the zonal succession, and it is in consequence likely to prove of more value for the purpose of scientific study than any other series of Speeton fossils preserved in a public museum. The collection is specially rich in belemnites from the upper part of the Kimeridge clay, and in ammonites and belemnites from the upper part of the zone of *Belemnites lateralis* and the lower part of the zone of *Belemnites jaculum*. Mr. Danford has been able to show that the faunas are less strictly separable at the junction of these zones than was formerly considered to be the case. Some of the ammonites in the collection have been used to illustrate a recent paper by Mr. Danford, and will be enumerated in the list of specimens figured during the ensuing year.

During the summer Dr. Ivor Thomas visited the Bristol neighbourhood, and, in company with Dr. A. Vaughan, examined sections in the Carboniferous limestone. The object of his visit was to obtain a fuller insight into the details of Dr. Vaughan's work on the zonal palæontology of the limestones, and so become better equipped to apply the results of this work in the palæontological investigation of the Carboniferous Limestone of other districts. To further facilitate this end, Dr. Thomas, with the collaboration of Dr. Vaughan, brought together a good reference set of zonally collected specimens, named in accordance with the latest results of Dr. Vaughan's researches. This series will serve in some measure as a standard, and should prove of great use for comparison, in view of the difficulty experienced in applying Dr. Vaughan's published results without the help of illustrative specimens, and the continued instability in the nomenclature of certain forms which are of significance from the point of view of zonal work.

Dr. Kitchin's examination of the Jurassic fossils collected in a previous year in the Island of Eigg has shown that the fauna throughout the Jurassic series in that locality, though rich in individuals, is relatively poor in the number of species. The Mollusca of the Great Estuarine beds are of interest, and they merit closer attention than it has been found possible to devote to them. Their investigation is rendered difficult by the usually poor preservation of the material and the lack of similar forms of like age from other districts with which they might be compared. The limits of age of the Great Estuarine series, as might be expected, are not to be ascertained from the fossils of estuarine character, but it is probable that the upper part of the series, as in the Island of Skye, may

be equivalent to a considerable part of the Oxford clay. The Oxford clay which here overlies the Great Estuarine beds is characterized by the prevalence of ammonites of the group *Cardioceras cordatum* (J. Sow.). The fact that some of these ammonites have reached the phase of development illustrated by *Cardioceras excavatum* (J. Sow.), suggests that strata of Lower Corallian age may be included.

Mention may be made of the interesting discovery of *Scyphocrinus* in Cornwall. Specimens obtained by Mr. Clement Reid and Mr. W. G. Fearnsides at Catasuent Cove, Porthluney, were submitted to Dr. F. A. Bather, who recognized the remains of "loboliths" and stems and arms of *Scyphocrinus*, a genus most characteristic of the Upper Silurian of Bohemia, but hitherto not found in the Anglo-Scandinavian basin. The specimens came from a limestone-lenticle in slates which contain included limestone masses of various ages. Dr. Bather infers that this particular block was of Lower Wenlockian age. The principal points of interest to which he draws attention are the additional evidence afforded by these specimens, firstly, for the connection between the fragments of stems and arms of *Scyphocrinus* with the structures known as "loboliths," and secondly, for the extended geographical distribution of this genus.*

Good progress has been made in revising the nomenclature of parts of the museum collection, and Mr. E. A. Newell Arber, Dr. Wheelton Hind, Dr. C. A. Matley, and Mrs. Shakespear have given assistance in this work. Mr. H. A. Allen has been engaged for some time in preparing a manuscript catalogue of the large series of Tertiary Vertebrata, and this is approaching completion. He also arranged a case in the museum for a temporary exhibit, where a selected series of the fossils newly acquired will be on view for some time before they are permanently placed in the collections. Examples of fossils mentioned in Mr. H. B. Woodward's memoir on "The Geology of Sidmouth and Lyme Regis" were selected and arranged by Mr. Allen for a case which has been allotted by Mr. Howe for the purpose of illustrating newly-issued memoirs. Other suites of specimens of this character will be exhibited in due course, and it is hoped that they will prove of help to readers of the memoirs.

Considerable progress has been made with the registration of specimens in the museum collection, and this work has been almost wholly carried out by Mr. S. W. Morgan. A useful instalment of Mr. Allen's catalogue of types and figured specimens in the museum, that section which comprises the Lamellibranchiata of the Oolitic rocks, was edited for the Press and published in the SUMMARY OF PROGRESS for 1905, pp. 175-195.

* F. A. Bather, "The Discovery in West Cornwall of a Silurian Crinoid characteristic of Bohemia." *Trans. Roy. Geol. Soc. Cornwall*, vol. xiii., pt. iii., pp. 191-197. Feb., 1907.

The following specimens in the Museum have been described or figured and described during the year.

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1906.

*Lower Palæozoic Trilobites*, Part 3.

By Mr. F. R. Cowper Reed, M.A.

Cybele verrucosa? *Dalman*, p. 129.
Cheirurus gelasinosus *(Portl.)*, *var.*, pl. xviii., fig. 7, p. 141.
Lichas (Platylichas) grayi *Fletcher*, *var.* scoticus, pl. xiv., fig. 8, p. 100.

*British Cambrian Trilobites.*

By Mr. Philip Lake, M.A.

Agnostus rotundus *Grönw.*, pl. ii., figs. 3, 4, p. 14.
„ rudis *Salter*, pl. ii., figs. 13-15, p. 21.

*Cretaceous Lamellibranchia*, Vol. II., Part 3.

By Mr. H. Woods, M.A.

Perna rauliniana *d'Orb.*, pl. xii., figs. 8, 9, p. 94.
„ sp., pl. xiii., figs. 2, 3, p. 99.
Astarte elongata *d'Orb.*, pl. xiv., figs. 2, 3, p. 102.
„ (Eriphyla) obovata *J. de C. Sow.*, pl. xvi., fig. 3, p. 113.
„ ( „ ) striata *J. de C. Sow.*, pl. xvii., figs. 3, 6, p. 116.
Cardita? fenestrata *(Forbes)*, pl. xviii., fig. 2, p. 121.
Cardita cottaldina *d'Orb.*, pl. xviii., fig. 15, p. 126.
Crassatellites divisiensis, n. sp., pl. xix., fig. 1, p. 128.

*British Pleistocene Mammalia*, Vol. II., Part 2.

By Prof. S. H. Reynolds, M.A.

Ursus arctos *Linn.*, pl. v., fig. 5; pl. vi., figs. 1-4.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOL. LXII.

By Dr. A. Smith Woodward, F.R.S.

Myriacanthus paradoxus *Ag.*, pl. i., fig. 5., p. 1.

By Mr. L. Richardson.

Dentalium giganteum *Phill.*, pl. xlv., fig. 16, p. 579.
„ minimum *Buckm.*, pl. xlv., fig. 13, p. 582.
„ subovatum, n. sp., pl. xlv., fig. 7, p. 587.

IN THE GEOLOGICAL MAGAZINE, VOL. III., 1906.

By Dr. H. Woodward, F.R.S.

Fouquea cambrensis *Allen*, p. 29.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOL. XVIII., 1906.

By Mr. R. G. Carruthers.

Cyathophyllum?, pl. ix., fig. 7, p. 356.

IN THE PROCEEDINGS OF THE COTTESWOLD NATURALISTS' FIELD CLUB, VOL. XV.

By Mr. S. S. Buckman.

Schlotheimia charmassei *(d'Orb.)*, pl. x., figs. 19, 20, p. 239.

## V.—MUSEUM OF PRACTICAL GEOLOGY.

Mr. Howe

This year an attempt has been made to initiate a series of exhibits in the museum that will illustrate the geology of the districts described in some of the new memoirs as they are published. It is feared that the exigencies of space and time will not permit of the preparation of an exhibit for every memoir; but, so far as it is possible, this will be done in the future.

The two districts for which illustrated exhibits have been set up this year are: Sidmouth, "The Geology of the Country near Sidmouth and Lyme Regis," 1906, with Sheets 326 and 340; and the Isles of Scilly, "The Geology of the Isles of Scilly," 1906, with Sheets 357 and 360. In each case numerous photographs and specimens are shown, with short descriptive labels. Owing to the necessity of changing these memoir exhibits from time to time they can be on view only for a limited period.

In the museum extension, the exhibit to illustrate the English China-clay and China-stone industry has been completed; and the collection of Road-stones has been considerably increased.

By the modification of one of the old cases on the principal floor, an effective exhibit has been made of some of the larger mineral specimens.

Most of the museum work during the year has been devoted to the re-organization of the storage accommodation.

# II.—SCOTLAND.

## I.—FIELD-WORK.

. Horne. The ground surveyed in the Highlands was arranged in two districts as follows:—

1. West Highland district, including South Knapdale, and the area between Glen Etive and Ben Nevis, under Mr. Clough, M.A.
2. North Highland district, containing parts of the counties of Ross, Inverness, and Caithness, under Mr. Hinxman, B.A.

The Carboniferous areas were arranged in two districts:—

3. Coatbridge and Motherwell district, with parts of the Campsie and Kilpatrick Hills, under Mr. Clough.
4. Glasgow and Denny district, under Mr. Hinxman.

In the West Highland district further progress was made with the mapping of the deer forest areas between Glen Etive and Ben Nevis (Sheet 53), and, in the autumn, field-work was resumed in South Knapdale, and Sheet 28 was finished.

In the North Highland district, the unfinished areas between Loch Carron and Glen Cannich (Sheet 82) were mapped, and that sheet is now completed. Field-work was continued to the north and west of the River Dulnan, in Sheet 74, and also in Caithness (Sheet 116). By the close of the Highland season Sheet 116 was finished.

Special attention was directed to the completion of the revision of the Carboniferous areas included in the Glasgow district map, and at the close of the year that sheet was completed, except a small tract composed of contemporaneous volcanic rocks and of Upper Old Red Sandstone.

Mr. Muff returned to his duties in Scotland at the end of October, after his temporary absence in British East Africa. Till the end of the year, he was engaged with indoor work, consisting chiefly of writing memoirs of areas surveyed by him.

Mr. Grabham left the field towards the end of July, and was occupied for the rest of the year in the office, completing the memoirs and maps of the areas which he surveyed, before his departure for the Soudan.

### 1.—West Highland District (Including South Knapdale and the Area Between Glen Etive and Ben Nevis).

Mr. C. T. Clough, M.A., District Geologist.
Mr. J. S. Grant Wilson.
Mr. W. B. Wright, B.A.
Mr. E. B. Bailey, B.A. — Geologists.
Mr. G. W. Grabham, M.A.

Mr. Clough was prevented from sharing in the mapping of the district by memoir work, which occupied most of his time during the Highland season. During a visit of inspection he took the opportunity of further examining, with some of his colleagues, a small area in the Glencoe district, about half a mile south of Dalness, in which the Beinn Cruachan granite and the diorite porphyrite—which is so often found along the Glencoe fault—were both known to occur. His previous impression that these two rocks were, in this area, separable from one another, was confirmed. The granitic rock appears to be the later of the two, but is not chilled at the margins. Dr. Horn

## HIGHLAND METAMORPHIC ROCKS.

### *Glencoe District.*

*Kinlochleven.*—Two main lithological types have been encountered this year among the crystalline schists. The one is a well-bedded quartzite, free from pebbles, which gives rise to many conspicuous hills in the area south-east of Ben Nevis, while the other is a grey mica schist, sometimes garnetiferous, which is not infrequently associated with thin bands of black schist and streaks of calcareous matter. The two types occur in a series of distinct belts, but, as yet, it is uncertain how far this distribution is determined by folding. Messrs. Wright a Bailey.

*Glen Creran District.*—The long ridge of Sgorr-a-Choise is capped by a pebbly quartzite of the Schichallion type, the southern margin of which is adjacent to considerable exposures of the Appin limestone,* and is often calcareous. On the north side of the hill the northern margin of the quartzite is chiefly in contact with black schists without the intervention of any fault, but on the east side of the Cairn a powerful fault crosses the hill, and throws black schist against different beds of the quartzite. Mr. Wils

*Glean Spean.*—On the north-east side of Ben Nevis a small area, mapped in the valley of Allt Coire an Eoin, was found to be chiefly occupied by a phyllite group resembling the upper portion of the Ardrishaig series, together with associated dykes and igneous masses.†

*Knapdale and Kilberry.*—In last year's SUMMARY OF PROGRESS an epidiorite, occurring with the basement beds of the quartzite, was described as a deformed pillowy lava, similar to those mapped by Dr. Peach‡ in association with the limestones and black slates of the Easdale group, on the west side of Loch Sween. Further examination has shown that this epidiorite resembles these lavas, not only in its pillow structure, but also in its highly-porphyritic character. There can be little doubt, therefore, that lavas belonging to one and the same volcanic series are intercalated both with sediments of Mr. Bail

* Summary of Progress for 1904 (*Mem. Geol. Surv.*), p. 63.

† These different rocks are referred to in the Summary of Progress (*Mem. Geol. Surv.*) for 1898, p. 45; for 1899, p. 41; and also for 1900, p. 28.

‡ Summary of Progress for 1903, p. 69.

the Easdale subdivision of the Loch Awe group, and also with the basement beds of the quartzite subdivision of the same group. It must be acknowledged, also, that the evidence adduced by Mr. Bailey in favour of an unconformability at the base of this quartzite in the neighbourhood of Cruach Lusach, about three and a half miles north of Achahoish, can no longer be maintained. It now seems more probable that the "upper calcareous zone" referred to in the table given in last year's SUMMARY (p. 93) belongs to the Ardnoe group of the quartzite series, rather than to the Ardrishaig series. If the correlation now suggested should prove correct, the quartzite group would appear, in this particular area, to be interbedded between the Easdale series and the Ardrishaig series.

## LOWER OLD RED SANDSTONE.

### *Volcanic Rocks, together with the Associated Sediments and Intrusive Rocks.*

ham. *Buchaille Etive Mor and Glen Etive.*—In the neighbourhood of Dalness the old land surface on which the lavas rest is very uneven, and hence the schists protrude at different levels through the lower lavas.

In this locality the andesites at the base of the series attain a thickness of 200 or 300 feet, and are followed by more acid rocks, such as rhyolites and perhaps dacites. Small masses of andesite are intercalated in the lower part of the rhyolite series, and, from their field relations, it seems probable that they may be either intrusions or may have been actual inclusions in the rhyolite flows at the time when these were poured out. The whole series has been more or less altered by the intrusion of the Beinn Cruachan granite.

On the north-east face of Stob Dearg the base of the volcanic rocks is irregular, but generally dips steeply towards the south-west at angles varying from 30° to 40°. On the north end of Sron Creise their base is even more highly inclined, but the angle decreases towards the Cam Ghleann. On Sron Creise, and on most parts of Stob Dearg, the members of the volcanic series were not bedded against the old land surface, and the old floor and the overlying breccias and lavas have now a common dip.

Several small intrusions occur in the volcanic series, some of which must be, at least, earlier than the Beinn Cruachan granite, as they have suffered alteration by it. The largest of these intrusions—a mass of red-banded felsite—forms the summit of Stob Dearg, and cuts across members of the volcanic series.

Bailey. *Glencoe.*—The chief addition to our knowledge regarding the Glencoe fault is the recognition that important movement and igneous intrusion occurred along it at more than one epoch. The sketch map in last year's SUMMARY OF PROGRESS

(p. 98), showed a boss of grey diorite porphyrite* of earlier date than the main intrusions associated with the fault. This boss has now been found to be bounded to the south, for a considerable distance, by a line of flinty crush running parallel to the main fault. The latter is in this locality accompanied by a narrow band of the more normal porphyrite which so often clings to the fault in other districts, and which may be called the fault-porphyrite. The earlier porphyrite and the fault-porphyrite, which is also a diorite porphyrite, are both chilled against the flinty crushes that form their respective southern boundaries. These phenomena might be explained on the supposition of the successive welling-up of molten material along two lines of movement which were in existence prior to either intrusion, but such a hypothesis will not account for the relations existing in the porphyrite mass a little further west. It has now been shown that in this mass both porphyrites occur side by side, but separated from one another by a flinty crush, parallel to, and not far distant from, the main fault. In this locality the fault-porphyrite is in fact limited to a somewhat narrow belt, bounded on either side by flinty crush, to which it presents chilled margins. It shows no sign of movement at either boundary, except some later brecciation. The earlier porphyrite, however, is intensely sheared, and, after its complete consolidation, has provided materials for the manufacture of the flinty crush-rock which separates it from the normal porphyrite. It is clear, therefore, that movements involving the production of flinty crushes recurred along or near the Glencoe fault both before and after the consolidation of the earlier of the two porphyrites. Movements seem, indeed, to have been repeated again and again along this line, and to have been attended or closely followed by igneous intrusion. Although the fault-porphyrite is not known to be affected by the movements of this period, it is quite possible that it was intruded before their cessation. In reference to this question, it should be noted that Mr. Clough has now shown that the various granite intrusions (Tablet 3 of sketch map in last year's SUMMARY) are not merely the coarser portions of the porphyrite masses, with which they are associated, but are sharply defined from the latter, though doubtless they are of closely connected origin. They should in all probability be regarded as outlying portions of the Beinn Cruachan granite, which, near Alltchaoruinn, transgresses the fault line and enters into the heart of the subsided area.

Mr. Grabham.

The Glencoe fault has been traced further round, south-east of Alltnafeadh, and crosses the Coupall River in two branches. The main branch forms the west boundary of the tonalite, and is not exposed in the river; but the smaller one is accompanied by a rhyolite dyke and a broad band of breccia, both of which are well exposed in the river about a mile and

* Numbered 4 on the map index.

a quarter from its mouth. In a good section of the main fault, in the Allt Cam Ghlinne (about a mile from the mouth of the stream), the tonalite is chilled against the flinty crush material of the fault. The belt of schists separating the tonalite from the base of the volcanic rocks shows many small lines of brecciation, accompanied by intrusions of felsite.

The tonalite intrusion which accompanies the Glencoe fault in this area differs in composition from the Beinn Cruachan granite, but the relations of the two rocks indicate that they must be closely allied in origin. Re-examination of the ground east of Clach Leathad shows that the more acid rock has sent veins into the more basic for a considerable distance. The intricacy of the junctions leads one to suppose, however, that the intrusions either followed immediately on one another or were separated by a very brief interval.

The junction of the Rannoch Muir granite with the tonalite intrusion* connected with the Glencoe fault has been further examined, and it is now evident that the tonalite has broken through the Rannoch Muir rock, and is therefore of later date. In the River Etive, about half a mile above the mouth of the Coupall River, the foliation of the Rannoch Muir rock is intersected by the line of junction of the two, while the minerals of the tonalite often lie parallel to that junction. About a mile up the Coupall River, also, numerous distinct fragments of the Rannoch Muir granite are included in the tonalite. The presence of boulders of granite in the basal conglomerates of the volcanic series has led to a search for masses which could supply these boulders, and it now appears probable that the Rannoch Muir granite was one of these masses, as a rock similar to it composes some of the boulders in the basal conglomerates exposed in Allt Cam Ghlinne. The Rannoch Muir granite itself, as previously pointed out by Mr. Kynaston† varies in appearance from centre to margin, and is relatively more acid at the margin than in the centre. The central phase is a grey foliated granite, consisting of quartz and oligoclase with subordinate orthoclase, biotite, and hornblende; but, towards the margin the percentage of orthoclase increases, and the rock becomes pink, while the hornblende diminishes and is absent at the margin.

Mr. Wright. *Kinlochleven.*—The more northerly of the streams known as Ruigh Breac, in the valley of Allt Coire na Ba, a mile and a half north of Kinlochmore, traverses an area of red breccia having vertical and irregular junctions with the surrounding schist, suggestive of a volcanic neck. The breccia contains angular fragments of schistose quartzite, and of a peculiar fine-grained red sandstone, as well as rounded pebbles of quartzite. A considerable quantity of basic igneous rock is also present.

* Summary of Progress (*Mem. Geol. Surv.*) for 1905, p. 99.
† Summary of Progress for 1900, p. 76.

PLEISTOCENE AND RECENT.

*Buchaille Etive Mor and Glen Etive.*—Boulders of Rannoch Muir granite were observed at altitudes of 1,500 feet on the face of Stob Dearg, and one was noticed on the *col* towards the south-west, at an elevation of nearly 3,000 feet. A fine set of terminal moraines has been mapped about a mile west of Alltchaoruinn, crossing the bottom of the valley on the north side of the stream. The material forming them shows distinct bedding dipping down the valley. Mr. Grabham.

ECONOMICS.

*Knapdale.*—The country lying between Tarbert, Ardrishaig, and Achahoish, contains a fair number of metalliferous veins, some of which were formerly worked for copper, lead, or zinc. The most important of these old workings was the lead mine on the south-eastern face of Cruach Mheadhonach (Sheet 28). There are also some old trial pits and adits in various parts of the district, the most extensive of which are those marked "Copper Mines" on the one-inch map, about a mile south of Meall Mor. The copper pyrites at this locality does not occur in veins, but is disseminated throughout the schist. A vein containing lead ore has recently been opened up at Stronchullin by Mr. Graham Campbell, of Shirvan, and is reported to yield several ounces of gold to the ton of ore. Mr. Wright.

## 2.—North Highland District—Comprising Parts of Ross, Inverness, and Caithness.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers.
Dr. J. Horne (Acting).
} Geologists.

HIGHLAND METAMORPHIC ROCKS.

*Ross-shire and Inverness-shire.*—The completion of the survey of Sheet 82 involved the carrying on of field-work during the past season in several disconnected areas on either side of the main watershed of Scotland. These areas are situated as follows: (1) round Achnasheen, on the Skye and Dingwall Railway; (2) on the south side of Loch Carron, between Attadale and Strome Ferry; (3) on either side of the River Ling, in the south-west portion of the map; and (4) in the south-east, between Glen Strath Farrar and Glen Cannich. Mr. Hinxman.

The complicated system of folds, with axes running north and north-east, which crosses the centre of the sheet, and has been described in previous reports, has been traced across the ground on either side of Loch a'Chroisg into the borders of the Fannich Forest, in Sheet 92. The rocks involved include the pelitic and siliceous members of the Moine series, together with two or more small masses or inliers of acid and basic gneiss of Lewisian type.

The ground mapped between Attadale and Strome Ferry is chiefly occupied by an inlier of Lewisian rocks, forming the core of an isoclinal anticlinal fold, and flanked on either side by the schists of the Moine series.

The central portion of the inlier consists mostly of a highly-felspathic gneiss of a crude type, in which the foliation is faintly indicated by interrupted folia and lenticles of biotite and hornblende. This central mass is bounded on either side by a belt in which the rock has undergone increasing deformation, until, along the margin, it assumes a more or less rolled-out or platy character. Hornblende rock in bands of varying breadth and large lenticular masses, and rocks which have the appearance of sheared pegmatite, make up a large proportion of the Lewisian area.

Along its western margin the gneiss is in contact with a platy dark grey mica schist, containing drawn-out lenticles of quartzo-felspathic material. This rock is considered to represent the pelitic gneiss of the Moine series, and is succeeded above by siliceous schists of the same series. A similar sequence is found along the eastern boundary of the inlier, but in the extreme south, at a point 1 mile S.S.W. of Lochan Iasgaich, the siliceous schist appears to overlap the grey mica schist, so that the Lewisian gneiss is at this point in contact with the higher member of the Moine series.

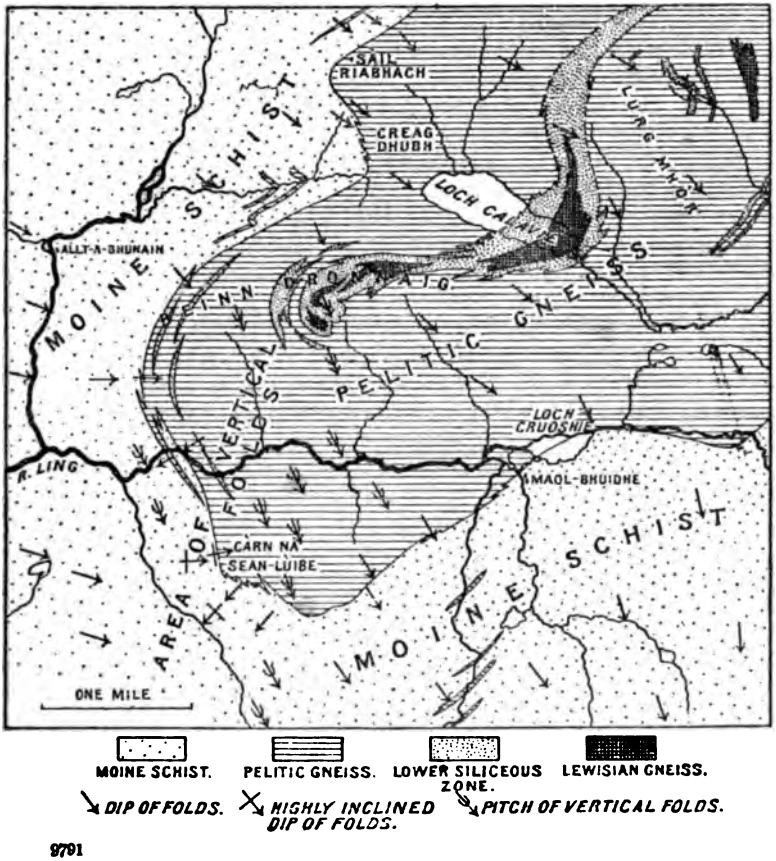
The detailed survey of the ground in the deer forests of Attadale and Kilellan (Area 3), by Dr. Crampton, has determined the stratigraphical position of the siliceous schists which extend across Sheet 82 from Glen Docherty to the S.W. margin of the map. They belong to the upper siliceous member of the Moine series, occupying the centre of a compound synclinal fold, and rest to the east upon the pelitic gneiss belt that crosses the West Monar Forest. Rocks representing the latter appear again on the western limb of the fold to the south of Attadale, as stated in the preceding paragraph.

The structural relations of the two zones in the Beinn Dronnaig area are of some interest, and will now be described.

The band of pelitic gneiss which crosses the centre of Sheet 82 has now been traced for a distance of 27 miles from the northern extremity on Sgurr Mhor Fannich (Sheet 92), to its southern termination on Carn na Sean Luibe, where it is abruptly truncated by a boundary line at right angles to the general strike. Along this boundary the pelitic gneiss inosculates with the overlying siliceous schist, the nearly vertical folds of the former pitching beneath the latter in a south-east direction, and giving rise to a jagged boundary line. The cause of this phenomenon is found in a sudden change in the direction and character of the folding which affects the beds in the immediate vicinity. Elsewhere throughout the area the rocks are isoclinally overfolded in a general N.W. direction, the limbs of the folds lying at low angles and dipping to the south-east. Along a line extending southwards from the summit of Ben Dronnaig, the country, however, is traversed by belts of vertical folding, the axes of plication striking N.W. and S.E., *i.e.*, at right angles to the axes of the gently inclined overfolds. These steep folds pitch to the south-east, in the same direction as the dip of the limbs of

the overfolds. The accumulated effect of these vertical folds causes the pelitic gneiss to plunge suddenly to a lower level along this boundary in a manner that simulates the effect of a monoclinal fold. Along the same line the overlying siliceous schists are also affected by similar belts of vertical folding in the area to the south of Carn nan Sean Luibe, where they have been followed for a distance of a mile. The structure described above is emphasized by the behaviour of a band of siliceous schist containing large individuals of muscovite and pellucid pale garnets, which has been traced for several miles from the N.E. within the outcrop of pelitic gneiss. On the summit of Ben Dronnaig this siliceous band becomes involved in the belt of vertical folding, and plunges steeply beneath the overlying pelitic rocks. With this siliceous rock on the mountain top are associated several small exposures of rocks of Lewisian type, including hornblende- and biotite-hornblende-gneiss and brown mica schist, similar to those of the inliers described in previous reports. This siliceous schist is consequently considered to represent the lower siliceous group of the Moine series, which underlies the pelitic gneiss.

FIG. 2.—*Map of the Beinn Dronnaig Area.*



Mr. Anderson.

*Glen Strath Farrar.*—The inlier of Lewisian Gneiss which extends from the western slopes of Sgurr na Lapaich in a north-easterly direction to Sgurr na Muice on the north side of the Farrar, has now been completely mapped. It includes two small masses of highly-crystalline limestone, accompanied in each case by graphite schist. Bands of calc-silicates are also frequently and widely distributed throughout the inlier, and a band, 12 to 15 feet in width, of almost pure epidote has been met with.

Further outcrops of the rock regarded as basal conglomerate, and described in last year's SUMMARY, are found to occur along the highly irregular eastern boundary of the inlier. The conglomerate forms part of the surrounding Moine schist, but is never far from the margin of the underlying Lewisian gneiss. At one point in this marginal portion of the Moine schist small patches of heavy minerals have been observed, indicating the sedimentary origin of the rock in which they occur. The minerals present are magnetite, epidote, and garnet, and are identical with those found in the alluvial deposit of the stream which flows over the Lewisian inlier.

To the east and south of this area of the older rocks lies a broad irregular band of siliceous Moine schist, succeeded further east by an area of alternating siliceous and pelitic or semi-pelitic bands.

Mr. Hinxman.

*Glen Cannich.*—The principal folds in which the members of the Moine series are involved, have been followed from Glen Strath Farrar southwards and westwards along the northern slopes of Glen Cannich to the edge of Sheet 82. The Lewisian gneiss occurs up to a height of nearly 2,500 feet on the eastern slope of Sgurr na Lapaich, but does not cross the watershed; the south-westerly pitch of the fold on which the inlier is brought up being so steep that the older rocks do not re-appear anywhere along the north side or the bottom of Glen Cannich.

The Moine rocks of this and of the preceding area do not differ essentially in lithological character from those described in last year's and former Reports. The predominant type in the pelitic group is the coarse, massive, garnetiferous gneiss which forms the high mountain ridge of Sgurr na Lapaich and Riabhachan. Further to the east a flaggy, fine-grained semi-pelitic variety is associated with the siliceous schist. A considerable area of the high ground between Sgurr na Lapaich and the top of Braigh a Choire Bhig is occupied by a flaky quartz-mica-granulite, highly felspathic, and characterized by an abundance of greenish-white mica and small pale garnets. The core of a small fold of similar rock mapped by Dr. Crampton on the north side of Sgurr na Lapaich is formed of Lewisian gneiss. It is therefore inferred that this muscovite-granulite represents the lower siliceous zone which in many localities lies between the pelitic group of the Moine series and the Lewisian complex.

*Faults.*—The course of the powerful fault which runs through Glen Docherty to Loch Maree has been traced from the head

of Loch a' Chroisg to the shore of Loch Gown, whence it is evidently continued in the dislocation which passes in a south-easterly direction to Scardroy, at the head of Loch Beannachan in the Strathconon Forest.

*Grantown and Dulnan Bridge.*—In the ground to the south-west of Grantown-on-Spey (Sheet 74), further progress has been made with the mapping of the group of rocks of the types described in last year's ANNUAL SUMMARY (p. 112). These include a coarsely crystalline white limestone or marble, associated with calc-silicate—a rock consisting almost entirely of tremolite being extremely frequent—a fine-grained mica schist with black mica as the predominant mineral, and a coarser muscovite-biotite-gneiss, in which kyanite is frequently developed. There appears to be more than one band of limestone, and the irregularity of the outcrops, as traced by the old workings, is due to the complexity of the folding. Mr. Anderson

The rocks as a whole appear to form an isolated patch surrounded by rocks of the Moine type. They are presumably referable to the Central Highland or Banffshire series, which occurs further to the east.

The fine-grained biotite schist is seen in contact with the Moine schist, and is either interfolded or intercalated with it. Rocks of Moine type also occur in close proximity to, and are probably contiguous with, another member of the group, a fine-grained quartzite, referred to in last year's Report (p. 113).

*Granite.*—The southern margin of the mass of Newer granite that lies to the N.W. of Grantown, has been traced from Cam Sgriob to Auchosnich. It is a fine-grained, pink, biotite granite, with occasionally a little white mica. The margin is very irregular, and veins and apophyses of granite and pegmatite pierce the schists for a distance of at least two miles from the margin of the mass, which also contains numerous inclusions of the schist. Higher up the Dulnan Valley a portion of the Monadhliath granite has been mapped to the west of Garbhmheall Mor. It presents the usual type of medium-grained biotite granite, occasionally finer-grained and porphyritic, and is pierced by a later intrusion of fine-grained aplite with phenocrysts of quartz and felspar.

*Carrbridge and Findhorn Area.*—Along the watershed between the Findhorn and the River Dulnan, a belt of siliceous Moine schist with occasional intercalations of pelitic schist has been traced for three miles south from the Slochd Mor on the Highland Railway. It is bounded on the east by a zone of muscovite-biotite-schist, exposed in the streams draining the eastern slopes. The general strike of the rocks in that area is N. and S. or N.N.W. and S.S.E. Dr. Horne

## MIDDLE OLD RED SANDSTONE.

*Caithness.*—As the result of his examination of the coast sections between Sarclet (south of Wick, and East Mey (west of John o' Groats), Dr. Crampton has suggested the following sequence of lithological groups in the Orcadian division of the Dr. Crampton

Old Red Sandstone strata of Caithness, given in descending order.

*Group* 8. *John o' Groat's Sandstone.*—Yellow and red false-bedded freestone, with a few thin bands of phosphatic blue flags and black bituminous shales containing fish remains.

7. *Mey Flags.*—Alternations of blue phosphatic and calcareous flags with fish remains, and white and greenish clays or mudstones. In the upper part bands of sandstone, like that of Group 8, are intercalated with the flags, and there are also boulder beds at several horizons.

6. *Noss Beds.*—Very rapid alternations of thin-bedded dark blue and black shaly flags, sandy beds, and lenticular bands of black limestone. The weathered surfaces show the peculiar "repousse ornament" markings similar to those described by Dr. Flett in the flagstones of Orkney.*

5. *Castle Sinclair Beds.*—Thick-bedded soft pale blue and greenish flags with fish remains, alternating with sun-cracked mudstones. Friable sandstones, accompanied by white clays and black bituminous shales with fish fragments, are locally developed at Ackergill, Keiss, and the south side of Sinclair's Bay; and a lower group of sandstones, and bituminous slates containing remains of whole fishes occurs at Field, north of Wick.

4. *Papigoe Beds.*—Alternating bands of pale blue and greenish calcareous flags, and smooth black calcareous slaty beds containing fish remains. The latter contain beds of blue limestone up to two and three feet in thickness.

3. *Wick Beds.*—Alternations of thick-bedded, coarse, dark flags; hard, grey, fine-grained sandstone; dark blue limestones, black slates, and papery black shales. The limestones are chiefly developed in the upper part of the group. The sandstones become thicker and more frequent downwards. Both the limestones and slates contain fish remains.

2. *Iresgoe Beds.*—Hard green and red shales, alternating in the upper part of the group with the grey fine-grained sandstones of Group 3, in the lower portion with the red arkoses of Group 1.

1. *Sarclet Sandstone and Conglomerate.*—Red, evenly bedded arkose passing downwards into a conglomerate with pebbles of granite, quartzite and schist, which probably forms the local basement bed of the formation.

The rocks of Group 1 are seen along the coast from Sarclet, northwards to Rieragoe, where they are succeeded by the shales and sandstones of Group 2. The Iresgoe beds occupy the cliff section as far as Craig Hammel, where the base of the next group (3) is brought down against them by a fault. Between Girston and the Brough, Group 2 is brought up again on a "ridge" fault, on the northern side of which the Wick beds (3) re-appear, and continue across Wick Bay to Broadhaven, where they are succeeded in natural order by the flags and slates of Group 4. The rocks of Group 5 now occupy the whole of the coast-line northwards from Staxigoe to Freswick Bay, with the exception of Noss Head, which is occupied by Group 6, on the downthrow side of a N.W.—S.E. fault.

A large fault, passing through Freswick Bay, brings down the John o' Groats Sandstones (8), on the northern side of the bay. At Skirsa Head the underlying group (7), appears, and forms the cliff section as far as Fa's Goe, where a fault with a downthrow to N.E. again introduces Group 8. Like Noss Head, the promontory of Duncansby Head is cut off by a fault, but is in this case occupied by rocks at a lower horizon (Group 7). Beyond this fault the sandstones of (8) form the

* *Trans. Roy. Soc. Edin.*, vol. xxxix., p. 406.

coast-line as far as John o' Groats, where a fault with a contrary throw brings in the underlying Mey flags once more. Lastly, in Gills Bay, we find the John o' Groats sandstones repeated in a small syncline between two faults at Ness of Quoys and Scotland Haven, the latter just outside the limits of Sheet 116.

Fossils have been collected from Groups 3, 4, and 5 and submitted to Dr. Traquair for determination. His report will be found in the Palæontological Section of this SUMMARY.

Whether the sequence of groups described above extends a long distance from the shore-line, and is due to climatic changes or other causes; or, on the other hand, is due to differences of sedimentation at various distances from that shore-line, remains to be proved.

*Area South of Watten.*—The ground surveyed by Mr. Carruthers included parts of Sheets 110 and 116, together with a small area in the north-east corner of Sheet 109. Mr. Carruthers.

The greater part of the area lies along the east and west watershed of the county, and is to a large extent covered by peat moss. The drift covering, as in most other parts of Caithness, is usually thin, and rock sections are exposed in most of the streams.

At various localities, wherever a calcareous band was observed, fish remains have been collected, and await the determination of Dr. Traquair. In the meantime it may be said that the whole of this area appears to be occupied by beds on or below the horizon of the Wick flags, and therefore within the lower portion of the Caithness flagstones. None of the characteristic fishes of the peculiar Achanarras fauna have yet been discovered within the area surveyed.

Over the greater part of the ground the beds are gently undulating, but a line of movement crosses the north-western corner of Sheet 110, about $1\frac{1}{2}$ miles N.W. of Balvreed. The red Berriedale flags are exposed in the small burn which flows into the Thurso River close to the head of Loch More, where they rest upon an inlier of the underlying floor of Moine gneiss, but within a short distance are seen to be overlaid by the metamorphic rocks, which have been brought up along a small, nearly horizontal thrust. The movement has evidently been from east to west.

## GLACIAL AND RECENT DEPOSITS.

In the Achnasheen area, the survey of the high-level terraces at the foot of Loch a' Chroisg has been completed. The highest of these terraces forms a wide peat-covered plateau with a gentle inclination from west to east, the western margin rising 605 feet above sea-level, or 100 feet above the present level of Loch a' Chroisg; the eastern margin 570 feet, giving a fall of 35 feet in nearly half a mile. No less than five lower terraces can be traced on the eastern side, to the south of old Ledgown Lodge. Most of these have probably been carved out Mr. Hinxman.

of the original deposit by the stream which flows out of Loch Gown. The sections exposed by the River Bran, which has cut a deep channel through these deposits, show the lower portion to be composed of finely-laminated clayey sand with occasional pebbly bands, obliquely bedded and often lying at a high angle. The upper part of the section consists of a coarse sub-angular and rounded gravel. In another section, lately exposed near the New Lodge, the laminated sand contains large angular blocks of gneiss lying at different angles.

The surface of the higher plateau shows several of the deep circular depressions—"kettle-holes"—so characteristic of these fluvio-glacial deposits. The margin of the higher terrace on the southern side is ill-defined, and seems to merge into the successive lateral moraines which flank the north-eastern face of An Liathanach.

That part of the terrace which lies to the south of the railway, between Achnasheen and Loch Gown, was mapped some years ago by Dr. Peach, who has suggested the following explanation of these interesting phenomena. The finer material in the lower part of the terrace, as first pointed out by Dr. Penck during a visit to the North-West Highlands from Vienna, was laid down as a delta deposit in an ancient lake, and subsequently covered by the coarse fluvio-glacial gravels. This lake appears to have occupied a position between the present foot of Loch a' Chroisg and a point in the Bran Valley, a short distance east of Achnasheen. Its waters were held up to the east by a lobe of ice protruded westwards up Strath Bran from the Fannich glacier, which moved southwards over the high ridge south of Loch Fannich and sent its main stream eastwards down the Bran Valley.

On the west and south-west of the lake, the valleys in which now lie Loch a' Chroisg and Loch Gown were also occupied by ice streams, in this case moving eastwards. At the retreating ends of these glaciers the material was delivered and laid down, first in the form of fine-grained material at the advancing front of the delta over which the coarser fluvio-glacial gravels were distributed.

*Glen Strath Farrar and Glen Cannich.*—The striæ observed along the ridge of high ground that separates these two glens, indicate that during the earlier stages of the valley glacier phase the ice streams that moved eastwards down each of these glens were confluent over the lower part of the watershed east of Creag Dubh. They further show that immediately to the east of that hill the ice passed out of Glen Cannich in an E.N.E. direction across the watershed, while evidence of a contrary movement of the Glen Strath Farrar ice at another period towards Glen Cannich is suggested by cross striæ found on the south side of Toll Odhar Mor, and others pointing south-east on the summit of Mullach Tarsuinn. Fine examples of the lateral and terminal moraines laid down by the valley and corrie glaciers are seen in the higher glens and corries on either side of the watershed.

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rson.

*Grantown and the Dulnan Valley.*—The town of Grantown-on-Spey is situated on a high level terrace of sand and gravel, 100 feet above the River Spey. The extremely irregular surface of this deposit to the west of the town indicates its probable fluvio-glacial origin. Mr. Anderson.

There is evidence to show that in late glacial times the waters of the Dulnan flowed northwards past Clachbain and round the end of Beinn Mhor through the well-marked hollow now occupied by the Glenbeg Burn. This hollow has been eroded in part of its course through the glacial deposits laid down in the valley at an earlier period, when the exits of the valley on either side of the hill were probably blocked by ice, and a sheet of water occupied the ground between Ryneckra and Shleanaferan.

*Carrbridge and Findhorn Area.*—The most interesting feature connected with the glaciation of the tract between the Slochd Mor and Carn Phris Mhoir is the evidence of overflow channels intersecting the ridge that runs N.N.W. from Carn na Larach (1,957) feet towards Press in the Findhorn Valley. Here there are three dry channels, varying from 25 to 70 yards in breadth, covered with peat or alluvium, and flanked by steep slopes of rock, which, in places, are capped with drift. The highest of these crosses the ridge at a height of 1,700 feet, the second about 1,500 feet, and the lowest about 1,400 feet. They evidently indicate stages in the recession of the Findhorn glacier, when the drainage of the water at the margin of the ice was deflected into the Dulnan Valley. Dr. Horne

*Caithness.*—Most of the drift-covered ground is occupied by the shelly boulder-clay laid down by the ice sheet which passed in a north-westerly direction from the North Sea over the Caithness Plain. The south-western limit of this deposit has been found to correspond fairly well with that laid down many years ago by Messrs. Peach and Horne.* Mr. Carruthe

The main valley system seems to be pre-glacial, the hollows being in general filled with drift, while on the higher ground the rock is close to the surface. As might be inferred from the low-lying nature of the region, the features due to powerful ice erosion are generally absent. A very perfect example of a rock basin is, however, found in Loch Stemster (110), where a rock margin can be traced completely round the loch.

The only glacial striæ referable to the land ice which moved outwards from the Morven range are seen on the roadside immediately north of Loch More. They point E. 17° N.

## ECONOMICS.

*Ross-shire.*—The areas mapped in Sheet 82 are all forest ground, and, with the exception of a few scattered houses at Achnasheen, practically without inhabitants or cultivation.

Material for the upkeep of the roads in the glens is obtained from the morainic drift at the roadsides.

* "The Glaciation of Caithness" (*Proc. Roy. Phys. Soc., Edin.*), vol. vi., pp. 316-352.

on. *Grantown and Dulnan Bridge.*—The town of Grantown is mostly built of a fine-grained mica-schist from the Dulach Quarries west of the town. The stone is not fitted for finer work, and Aberdeenshire granite or Elgin sandstone is used for lintels and ashlar. A more fissile schist was at one time quarried for "slate," but is no longer in use. The limestone referred to in last year's Report has been wrought in a number of small quarries between Braes of Muckrach and Gaich, but is not nearly exhausted. Some of the beds are so pure that they might possibly be used as marble.

The 'rubble' from the Dulach schist quarries is used for road-metal in the Grantown district.

A considerable amount of ground in this district is under timber, the plantations consisting chiefly of Scots fir (*Pinus sylvestris*). Otherwise the greater part of the ground is grazed by sheep or cattle, though some of the lower hill slopes are cultivated, the soil in places being enriched by the presence of limestone.

on. *Caithness.*—The flagstones of the Thurso and Watten districts afford an important but, on the whole, a decreasing industry. They are wrought for paving-stones and roofing-slabs, which are carried, chiefly by sea, to different parts of Great Britain. The inferior qualities of stone are used locally for building and fencing purposes. The principal quarries are those of Sir Tollemache Sinclair, in the Thurso district (four); and those wrought by the Caithness Flagstone Company at Holburn Head, four in the parish of Olrig, and seven in the parishes of Halkirk and Watten. There is some reason to believe that the rock quarried at Spital and Achscrabster, in the last-named district, lies at a considerably lower horizon than that of the Olrig and Thurso Quarries.

This distribution of the various quarries is mainly due to the presence of bands of rock of a certain quality, but is also influenced by convenience of carriage.

The sandstones of John o' Groats, and the harder sandstone bands in the Wick beds, are used locally for building purposes, while numerous smaller openings in the flagstones are wrought intermittently for fencing-slabs, building-stone, and road-metal for local use.

hers. An excellent supply of sand for the saws employed in the extensive flagstone quarries of Spital is obtained from a quarry near Leavad, five miles south of Spital. The sand is derived from the disintegration of a yellowish-white calcareous freestone, mammillated bosses of which remain on the walls and floor of the quarry, presenting a curious appearance.

Road-metal is obtained throughout the district from small quarries opened every few hundred yards along the roadsides. The hard nature of the local flagstones, and the scanty covering of drift, afford a suitable and readily procurable material.

## 3.—Coatbridge and Motherwell District, with Parts of the Campsie and Kilpatrick Hills.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A.
Mr. E. B. Bailey, B.A.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. G. W. Grabham, M.A.
} Geologists.

### Volcanic Rocks of the Calciferous Sandstone Series, together with the associated sediments and intrusions.

Mr. Grabham.

*Kilpatrick Hills.*—During last season the upper part of the volcanic series was examined, and some important beds of ash were mapped. Petrographical examination has revealed the presence of mugearites, and it has been found that these peculiar rocks are abundant towards the top of the series, south of Craigton.

Several intrusions have been met with among the lavas. About a quarter of a mile north of the farm of High Craigton three separate masses occur in the form of small irregular plugs or dykes, which may represent feeders of some of the flows, as they resemble the lavas in petrographical characters. Another mass, composed of non-porphyritic dolerite, is well exposed in the neighbourhood of Mugdock, and, though no section of its actual margin has been found, it appears to cut across several beds of lava and is presumably intrusive. The microscope shows that the rock is an ophitic dolerite, but, as the presence of neither quartz nor olivine can be determined, it is doubtful whether it belongs petrographically to the lavas or to the quartz-dolerites. The structure of the rock and the colour of the augite indicate affinities with the latter.

The volcanic series is bounded by east and west faults along most of its southern margin, but towards the east the conglomerates at the base of the Craigmaddie Muir sandstone rest conformably on the uppermost flows.

Mr. Bailey

*Campsie Fells.*—The division of the lavas into an upper porphyritic group and a lower group without conspicuously porphyritic members has proved of great service in unravelling the structure of the volcanic plateau; but exceptional bands sometimes occur, and it has been found necessary to follow in detail the outcrops of minor subdivisions. One of the latter has been traced through an area of 20 square miles and is very seldom absent, although frequently represented merely by a single flow—an easily recognizable porphyritic basalt. A further characteristic of the upper portion of the sequence is the association with the porphyritic basalts of many lavas with close affinities to the mugearites. Such an association of mugearites and porphyritic basalts is characteristic of the "plateau" eruptions of Mid and East Lothian, and has already been recognized by Mr. Grabham in the Kilpatrick Hills

The area of the volcanic neck of Meikle Bin has been con-

siderably extended beyond the limits previously mapped by Dr. Jack.

r
ıderson. In the southern part of the Campsie Fells, eastwards from the meridian of Lennoxtown, and extending as far as the Black Hill, the various flows of lava preserve their flatly-bedded character, with only gentle undulations. In the upper group three different porphyritic horizons occur, which were first mapped by Mr. Bailey in the area further west. The lowest is inconstant, and dies out towards the east; the middle one can be traced right through this district, and the topmost horizon occupies the summits of all the hills from a point north of Lennoxtown to half a mile from Birkenburn Reservoir. The highest horizon must be of considerable thickness, and probably consists of more than one flow.

Between these three horizons the flows consist of non-porphyritic basalts, and probably in part of mugearites. One belt of less basic rock, which is probably mugearite, runs for some distance along the southern front of the hills just below the topmost porphyritic flows. In this district, as elsewhere, the lavas are cut by a set of dykes which belong roughly to the same period of igneous activity, and also by the later east and west dolerite dykes. Among these latter are some which follow the course of the boundary fault along the southern margin of the volcanic plateau.

### MILLSTONE GRIT AND COAL MEASURES.

r. Clough. An important bore, called the Burnlip bore, is now being put down, in a position about 410 yards W.N.W. of Palace, rather more than a mile north of Coatbridge, by Messrs. Wm. Baird & Co. Ltd., who have allowed the cores to be regularly examined by the Geological Survey. The bore is intended to prove the position of the Limestone coals, but the Index Limestone overlying that group has not yet been reached. The highest strata no doubt belong to the Coal-measures, but at a depth of about 77 feet, a series, containing a great proportion of sandstone, is reached, which must represent in the main the Millstone Grit, though the top is perhaps not exactly on the same horizon as that adopted elsewhere. After piercing 294 feet of sedimentary beds belonging to this series a shelly calcareous shale or impure limestone,* about 5 feet thick, was pierced, and 24 feet below this band another limestone, 2 feet thick. Neither of these two limestones resemble the Castlecary limestone (the highest member of the Carboniferous limestone series) as it is developed in the best known sections, but the upper one closely resembles the impure limestone or "cement" which Mr. Tait has found a little above the Castlecary limestone near Castlecary, being characterized, like it, by abundant specimens of *Orthotetes*. It appears probable, therefore, that the lower band is in the position of the Castlecary limestone.

* The average dip of the strata is about 10°, and the true thickness must accordingly be about 291 ft.

Mr. Wrigl

A point of considerable interest has arisen about the identification of the coals worked, under the names of the Virtuewell and the Kiltongue, at Gartcraig Colliery, Millerston. Mr. Swan, the Manager of Gartcraig Fireclay Works, has long suspected that the uppermost of these coals is the Kiltongue, and that the other, known as the Kiltongue, is really some lower coal. The same opinion had previously been expressed by Messrs. McCreaths and Stevenson, to whom we are indebted for much of the evidence bearing on the question. In the first place, the distance of 29 fathoms between the coals just mentioned agrees with the distance between the Kiltongue and Balmoral seams at Lochwood Colliery, Commonhead, 3 miles east of Gartcraig, and is far too large for the average distance between the Virtuewell and Kiltongue in the district.

A massive sandstone from three to four fathoms thick above the so-called Virtuewell coal at Gartcraig, corresponds very well with that commonly found above the Kiltongue seam, and the sandstone above the true Virtuewell never seems to attain this thickness in the neighbourhood.

Mr. James McCreath remembers having seen débris of musselband in the tip of Gartcraig shaft before it had been sunk as far as the so-called Virtuewell coal, and he thinks that it probably came from the well-known musselband about nine fathoms above the Kiltongue seam. The lower coal at Gartcraig closely resembles the coal to which a shaft has been recently sunk at Lochwood Colliery, Commonhead. The chief point of resemblance is the occurrence of a brownstone rib in the body of the coal. The Lochwood coal is 28¼ fathoms below the Kiltongue. It is called the Balmoral by the Lochwood Coal Company.

Mr. Dunn, of Wester Daldowie, thinks, however, that this coal, which is characterized by a brownstone rib, is the Armadale or Bathgate Main coal. He states that this coal is everywhere characterized by the same stone rib or ribs, and he regards it as equivalent to the Brightons Main at Falkirk, and the Kilsnachtan Main at Alloa.

Mr. Cloug

The strata covering much of the area south and south-west of Coatbridge were placed in the upper group of barren red sandstones of the Coal-measures in the old editions of the Geological Survey Maps. A good section of these beds is exposed in the burn—called the Luggie Burn on the six-inch map—between the south-east end of the Green Park, Drumpellier, and the railway viaduct south of Drumpark. Here they consist mainly of red, soft, false-bedded sandstones, often with deep red blotches, and purple, red or buff shales and clays, with thin seams of cream-coloured limestone, which are rarely more than an inch or two thick, and are frequently associated with very thin black laminæ. The series as a whole closely resembles the red barren series of the Mid Lothian basin and of Fifeshire, but has not yet yielded any fossils which suffice to decide to which division of the Coal-measures it should be referred. It must be remembered, however, that the similar series in Fife

shire has provided a considerable list of fossils, and is referred by Mr. Kidston to the Middle Coal-measures of England.*

The red beds of the burn south of the Green Park are bounded on the south by a large east and west fault, with an upthrow to the south of about 100 fathoms, and on the south side of this dislocation, a thick series of beds is found in which the shales (blaes) are mostly of a grey colour, though reddish sandstones are sometimes mixed with them. Near the base of this series the crop of the Upper Coal of Glasgow has been proved in the workings of Kirkwood United Colliery (west of Old Monkland), and none of the beds exposed in the North Calder, between Bredisholm and Bankhead, can be referred to so high an horizon as those in the burn near the Green Park. They contain various thin coal-seams, and have yielded a number of fossil plants which are all referred by Mr. Kidston to the Lower Coal-measures (Lanarkian). Still further south, thick red sandstones, which may be as high in the sequence as those near the Green Park, supervene, in consequence of the general southerly or south-easterly dip, but they are not well exposed. In the North Calder, about a quarter of a mile S.S.E. of Bankhead, beds of the type of the Upper Barren series, with purple shale and a thin creamy limestone, appear to alternate with beds of the common grey type.

A marine band containing *Productus scabriculus, Discina nitida, Conularia quadrisulcata, Bellerophon Urii*, a shell like *Axinus deltoideus*, and crinoid stems was described by Mr. R. White Skipsey† many years ago from Drumpark Pit, from a position about 53 fathoms above the Upper Coal of Glasgow, and also from an adjoining pit.‡ It seems probable that this marine bed is on the same horizon as one described in Fife-shire by Mr. J. W. Kirkby, which occurs about 40 feet below the line adopted as the base of the Upper Red Beds in that county.§ It may be recalled that in Mid Lothian also a marine band occurs immediately below the Upper Red Beds.‖

### INTRUSIVE DYKES IN THE COAL-MEASURES.

Mr. Clough. At least three thin decomposed dykes of dolerite cross the North Calder between Bankhead and Woodhead, and others have been cut in the adjacent mines. They all strike nearly W.N.W., and perhaps are of Tertiary age, but no specimens

* Vice-President's Address "On the Various Divisions of British Carboniferous Rocks as determined by their Fossil Flora," *Proc. Roy. Phys. Soc.*, vol. xii., p. 204, 1893. "The Geology of Central and Western Fife and Kinross" (*Mem. Geol. Surv.*), p. 146, 1900.

† "On the Discovery of Carboniferous Limestone Fossils in the Upper Coal-measures to the East of Glasgow," *Trans. Geol. Soc. Glasgow*, vol. ii., p. 62, 1865. "On the Range and Occurrence of Anthracosia and other Shells in the Coal-measures Eastward of Glasgow," *Trans. Geol. Soc. Glasgow*, vol ii., p. 144, 1866.

‡ Probably Bargeddie.

§ "On the Occurrence of Marine Fossils in the Coal-measures of Fife," *Quart. Journ. Geol. Soc.*, vol. xliv., p. 747, 1888. "The Geology of Central and Western Fife and Kinross," p. 147, 1890. (*Mem. Geol. Surv.*)

‖ Summary of Progress for 1903 (*Mem. Geol. Surv.*), p. 113.

have yet been obtained in a sufficiently fresh condition to enable their microscopic characters to be satisfactorily determined. Specimen 12,695, from one of the dykes in Ellismuir Pit No. 3 —about a quarter of a mile west of Bredisholm (house)—is called by Dr. Flett an olivine dolerite. Some of the dykes are accompanied with small faults, and the Ellismuir dyke just referred to is seen in the workings to be veined, as if it had itself been slightly crushed, but the strata south-west of the dyke are broken by a small fault, along which thin strings of the igneous rock are found as if they had proceeded along pre-existing lines of weakness. It seems probable, therefore, that some of the fault movements preceded while others succeeded the intrusion.

The coals at the sides of the dykes are "burnt," and rendered unsaleable for a slight distance, and close to the dykes they are jointed into columns at right angles to the adjacent side of the intrusion, and are ofter heavily charged with carbonates, in small blebs or areas of irregular shape, which can be distinguished by the naked eye.

## PLEISTOCENE AND RECENT.

Mr. Wright

The remarkable drumlin topography which characterizes the district between Glasgow and Coatbridge is interrupted along a narrow belt of country extending from the Monkland Canal north of Hallhill in a southerly direction through Springhill and Muirside to Calderpark. Within this area, which is two miles long and has an average width of about half a mile, the east and west drumlins are replaced with irregular mounds which have neither the symmetry and elongated form of drumlins nor the steepness and delicacy of curve which one sees in an area of gravel mounds. They appear to be everywhere composed of a light loamy type of boulder-clay passing in places into pebbly sand. The northern end of the belt abuts against the high ground to the north of the Monkland Canal, while to the south it passes beneath or is cut off by the well-marked area of gravel mounds which fringes the Clyde Valley. An extensive deposit of gravel lying to the east of the belt at Swinton may be connected with it. This, however, is not obvious, nor indeed is the meaning of the remarkable belt of mounds itself.

Mr. Clough.

Near the burn, south of the Green Park, Drumpellier, two divisions of boulder-clay are exposed, the upper one of a red and the under one of a dark brown colour,* and in some sections several thin alternations of these varieties of clay are found between the main masses of each.

Large deposits of sand, forming somewhat uneven surfaces, occur west and north of the Green Park, Drumpellier. Sand has also been proved in drains along a great part of Bank Street, Coatbridge.

Extensive peat mosses almost connect Bishop Loch with

* Two boulder-clays of different colours, the upper one red, were described in last year's Summary of Progress, p. 102, by Messrs. Hinxman and Carruthers.

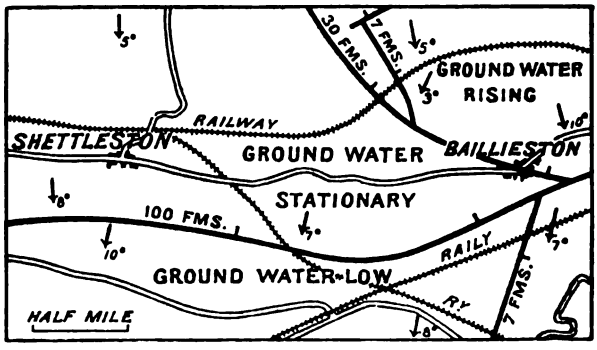
Woodend Loch, and with Lochend Loch, north-west of Coatbridge. On the west side of the last-mentioned loch the moss has been proved by three borings to be as much as 23 feet deep. In most parts of these mosses large roots of the Scottish fir (*Pinus sylvestris*) are very abundant near the top, but between Lochgreen and Heatheryknowe House, oak is more commonly found.

ECONOMICS.

Mr. Wright. Owing to the exhaustion of the higher coals in the neighbourhood of Shettleston, interest is now centred on the lower seams. The Kiltongue and the Lower Drumgray are both being worked, the former pretty extensively. A still lower coal, about 27 fathoms below the Kiltongue, has been mined at Gartcraig, and proved by shafts in other parts of the district. The occurrence in the body of this coal of a stone rib, which is not easily separable from it, makes it doubtful whether it can be put on the market with profit. It is used at Gartcraig for the special purpose of firing bricks manufactured from the underlying fireclay which is mined along with it.

The statement concerning the exhaustion of the higher coals requires modification with regard to the stretch of country lying between Carntyne and Baillieston. Here the coals from

FIG. 3.—*Plan showing distribution of Ground-water near Shettleston.*




the Upper to the Main are indeed almost completely worked out, but the Splint and Virgin are only partially so, and the lower coals are untouched and likely to remain so. The obstacle to further working is the occurrence here of a great mass of ground-water which is held up on the north side of the 100-fathom fault which runs east and west through Springfield and Baillieston. This great dislocation is joined by a north-westerly fault at Baillieston, and the western angle between these is occupied by this ground-water. Since the year 1881, it has maintained a uniform level of 49½ feet above Ordnance datum, determined by the overflow at Camlachie, near Parkhead, where the surplus is used for washing purposes in a distillery. Owing to the presence of this ground-water in the old workings of the Main Coal over the area mentioned, it has

up to the present been found impossible to get at the unworked coals, since pumping might result in damage to the buildings in Shettleston. To the south of the 100-fathom fault, the ground-water is kept low by pumping. North of it, and east of the above-mentioned fault, which joins it at Baillieston, the ground-water is steadily rising, and many of the mines in this district are in danger of being flooded out.

Mr. Clough.

The rise of the ground-water in the area just referred to is due to the advance of water along abandoned workings, &c., from the east. It has only become a serious matter recently, but near Coatbridge the advance has been very rapid and has led to the stoppage of five pits since last June. The commencement of the rise is attributed to the cessation of pumping in two pits near Calderbank, which had been worked out, but, of course, as the number of pits that cease working and pumping increases, the advancing ground-water will proportionately increase in amount. As far as our present knowledge goes, this water has not yet penetrated into any pits working on the south side of the large east and west fault referred to in the preceding paragraph, which extends eastwards from Baillieston through Old Monkland and the Rosehall Coalfield. The crush-rock of this fault has been cut through in No. 11 Pit, Rosehall, and in the stone mines driven northward from this pit. The advancing water finds its way along these stone mines on to the south side of the fault and, if it were allowed to ascend upwards into the upper part of the pit shaft, it would come within 70 yards of the Lower Drumgray workings on the south side of the fault and might gradually find its way through some of the strata into these workings, and then pass into very important coalfields further south. A strong concrete dam has been built in the lower part of the shaft referred to, and it is hoped that it will be able to resist the upward pressure of the water.

At the Drumpark Brick Works, Messrs. Dewar and Finlay are using red sandy clays of the Upper group of barren red sandstones for the manufacture of both red and blue bricks, of the Staffordshire type. The latter are made at a higher temperature than the former, and with the exclusion of unnecessary air, so that the red iron oxides, which are present in the raw material, become reduced. Prof. R. Stansfield, of the Heriot Watt College, has tested the crushing strength of specimens of both these types of brick of the ordinary size (9 in $4\frac{1}{2}$ in. × 3 in.), and frogged on both sides, and he found that the crushing stress of the red brick was 2.13 tons per sq. in. (= 307 tons per sq. ft.), and of the blue brick 2.25 per sq. in. (= 324 tons per sq. ft.). Professor Stansfield states that the strength of the red brick is in excess of that of the best common brick, and that the blue brick is practically equal in strength to the ordinary Staffordshire blue brick.

Mr. Grabham.

*Kilpatrick Hills.*—An abundant supply of road metal is furnished by quarries in the lavas and intrusive igneous rocks. Gravel and sand are obtained from pits in the gravel terraces near Blanefield.

## IV.—Glasgow and Denny District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. J. S. Grant Wilson
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers
} Geologists.

Mr. Hinxman.

Acknowledgment must again be made of the assistance afforded during the progress of the Survey by colliery proprietors and managers, mining engineers and others, in supplying valuable mining and other underground information.

### Millstone Grit and Coal-measures.

The consideration of the bores and shafts put down since the original Survey of 1868 in the north-eastern suburbs of Glasgow, has led to a considerable modification of the existing map. The area coloured as Millstone Grit between the outcrop of the dolerite sill south of Hogganfield Loch and the railway line north-east of Alexandra Park, is found to be occupied by Coal-measures. The thin coals and fireclays proved in the shallow bores put down about Blackhill and Riddrie, represent the position of the Armadale coals at the base of the series, while the seams formerly worked to the east of Provanmill Distillery and in Riddrie Park, as respectively the Kiltongue and Virtuewell, lie at a lower position and are now considered to be the Armadale Main and Kiltongue coals. The base line of the Coal-measures has, therefore, been drawn southwards from the fault near Low Balornock along the railway line to the Alexandra Park, and thence westwards along the north side of the Alexandra Parade into the dolerite sill of the Necropolis. An assemblage of fossils, characteristic of the slaty-band ironstone position, has been obtained from the cutting at Burnbank, where this base line crosses the City Union Railway, as well as from the dark shales at one time exposed along the Alexandra Parade west of the park.

Additional mining evidence obtained in the Carntyne and Parkhead districts has led to some slight alteration in the outcrops of the higher coal seams and in the course of the faults in that part of the map.

r. rampton.

The small isolated area of Coal-measures which includes the Coneypark, Livingston and Banknock coalfields, forms a strip about $3\frac{1}{2}$ miles in length by $\frac{3}{4}$ mile in width, in which the strata are disposed in two small basins separated by a gentle anticline in the centre of the area. On its northern side the Coal-measures are brought against the Carboniferous Limestone series by a powerful east and west fault, while on the south they have been proved to be faulted down against the Millstone Grit in the Livingston and Banknock fields. The relations of the Coal-measures to the other rocks south of the Coneypark field have not yet been determined. The recent information obtained shows that the Banknock field contains a fuller complement of coals, and extends further to the east than formerly

represented, and pits have been sunk to work the lower coals beneath the hard coal (No. 3).

The following section of the Banknock and Livingston fields, giving the local name of each seam, is compiled from data kindly supplied by the Colliery Managers:—

| Banknock Field. | Ft. | in. |
|---|---|---|
| Strata, 21 fathoms. | | |
| 1.†Soft Coal No. 1, 3 ft. 6 in. to | 4 | 4 |
| Strata, 9 fathoms. | | |
| 2.†Soft Coal No. 2 ... ... | 1 | 4 |
| Strata, 2 ft. to 5 fathoms. | | |
| 3.†Splint Coal, 2 ft. 2 in. to | 2 | 6 |
| Strata, 3 to 4 fathoms. | | |
| 4.†Hard Coal, 2 ft. 6 in. to | 2 | 9 |
| Strata, 11 fathoms. | | |
| 5.*Splint Coal, 1 ft. 6 in. to | 2 | 9 |
| Strata, 15 fathoms. | | |
| 6.*Virtuewell, 2 ft. 3 in. to | 3 | 6 |
| Strata, 4 ft. to 6 fathoms. | | |
| 7.*Ladygrange, 2 ft. 9 in. to | 3 | 4 |
| Strata, 9 to 12 fathoms. | | |
| 8.*Shale Coal, 1 ft. 7 in. to | 1 | 10 |
| Strata, 5 fathoms. | | |
| 9.*Main Coal ... ... | 3 | 6 |
| Strata, 1½ fathoms. | | |
| 10. Lower portion of Main Coal ... ... ... | 1 | 1 |
| Strata, 3½ fathoms. | | |
| 11.*Lower Splint ... ... | 2 | 3 |
| Strata, 2½ to 3 fathoms. | | |
| 12.*Upper Drumgray ... | 2 | 6 |
| Strata, 6½ fathoms. | | |
| 13. Middle Drumgray ... | 2 | 4 |
| Strata, 8 fathoms. | | |
| 14. Lower Drumgray ... | 1 | 6 |
| Strata, 8½ fathoms. | | |
| 15. Ball Coal, 1 ft. 5 in. to | 2 | 0 |
| Strata, 6 fathoms. | | |
| 16. Coal ... ... ... | 2 | 0 |
| Strata, 3 fathoms. | | |
| 17. Red Ironstone ... ... | 0 | 7 |
| Strata, chiefly Red and White Sandstone, 26 fathoms. | | |

| Livingston Field. | Ft. | in. |
|---|---|---|
| 6.†Virtuewell ... ... | 3 | 4 |
| Strata, 17 fathoms, with thin coal. | | |
| Oil Shale, 9 in., and Mussel-band, 7 in., resting upon. | | |
| 8.*Shale Coal ... ⅛ ... | 1 | 8 |
| Strata, 5½ fathoms. | | |
| 9.*Mussel-band 6 in, and Main Coal ... ... | 4 | 1 |
| Strata, 3 fathoms. | | |
| 10.*Pavement Coal ... ... | 1 | 8 |
| Strata, 5 fathoms. | | |
| 11.*Mussel-band and Lower Splint ... ... ... | 2 | 6 |
| Strata, 4½ fathoms. | | |
| 12.*Jewel Coal ... ... | 2 | 0 |
| Strata, 6 fathoms. | | |
| 13. *Upper Drumgray ... | 2 | 11 |
| Strata ... ... | 8 | 0 |
| *Lower Drumgray ... | 2 | 6 |
| Strata, 5 fathoms. | | |
| 14. Mill Coal ... ... | 1 | 8 |
| Strata, 5 fathoms. | | |
| 15.*Ball Coal... ... ... | 2 | 0 |

CARBONIFEROUS LIMESTONE SERIES.

Mr. Hinxman.

The mining operations at present going on within the Carboniferous limestone area that lies between Lenzie and Mollinburn on the north, and Garnkirk and Glenboig on the south, have afforded additional information which confirms the

† Coals worked out.
* Coals being worked at present time.

views as to the structure of the ground put forward in last year's SUMMARY (p. 120).

The faults which cross the area in a N.W. and S.E. direction are of considerable economic importance. Their upthrow being in each case to the east, their cumulative effect is to bring the valuable coking coals which lie beneath the Index limestone nearer to the surface in the eastern part of the field than would otherwise have been the case.

An isolated outcrop of the Calmy limestone round a small dome has been mapped immediately to the east of Chryston Village. The Hirst coal appears beneath it, and the correlation is further strengthened by the collection by Mr. Tait of the lamellibranch *Edmondia punctatella* from the shales, a few feet below the limestone.* This fossil has been described by Dr. Wheelton Hind, and has also been obtained from the shale beneath the Calmy or Arden limestone at Linn Spout, Dalry, in Ayrshire, and at Darnley and Thornliebank in Renfrewshire.†

Limestones also occur at two very constant horizons between the Calmy and the Index positions, and have been proved in almost every bore and shaft put down in this field. The higher band, one foot to fifteen inches in thickness, lies from 24 to 30 fathoms below the Calmy; the lower, seven inches to 11 inches thick, and often in two bands, rests at a distance of 40 to 48 fathoms above the Index. Both bands, as seen in cores, are dark grey, calmy or cement limestones. They also occupy very similar positions, with regard to the Calmy and the Index, as do the Orchard and Lyoncross limestones in the area south and south-west of Glasgow, and may, with some confidence, be correlated with them; especially as a limestone, 25 fathoms below the Calmy, has been recognised as the Orchard at Hillhead, in the intermediate area immediately north-east of Glasgow. A thin seam of dark, impure, ferruginous limestone, containing marine fossils‡ has been passed through in the "Black Metals," 82 fathoms below the Index limestone, in sinking the Bedlay shaft, one mile north of Glenboig. This is the first record by the Survey of fossils from this horizon, and, with regard to the wide extent of the strata known as the "Black Metals," of importance as proving their marine origin.

A new and important feature in the economic development of North-East Lanark is the opening up of the Carboniferous Limestone coalfield to the east of Glasgow, already referred to. Two shafts have already been sunk in the eastern and western parts of the field to the valuable coking coals which lie beneath the Index limestone. The principal seams are four in number, and are known as the Meikle Hill Main and Wee, the Bannockburn Main, and the Kilsyth Coking Coal. The

* See Palæontological Appendix with reference to the occurrence of *Edmondia punctatella* in shales beneath the Calmy limestone in the West of Scotland (p. 108).

† *Edmondia punctatella* Dr. W. Hind, Monograph British Carboniferous Lamellibranchiata, vol. ii., p. 148. (*Palæontograph. Soc.*)

‡ See Palæontological Appendix, p. 109.

Meikle Hill Main lies at an average depth of 28 fathoms below the Index limestone, and the Wee 3 to 5 fathoms below the Main. The seam or seams correlated with the Bannockburn Main Coal are found about 30 fathoms beneath the Meikle Hill Main. The vertical distance between the Index and the Kilsyth Coking Coal varies from 104 to a little over 120 fathoms, the thickness of strata between the latter seam and the Meikle Hill Main Coal apparently increasing towards the west.

COAL-MEASURES.

Mr. Carruthers.

*Rutherglen.*—Considerable alterations and additions have been made in the small area revised by Mr. Carruthers around Rutherglen. The outcrop of the various seams below the Splint Coal between Bankhead and Kirkhill, and the course of the faults affecting them, have been added to the map, and will, it is hoped, prove of use when these thinner coals come to be worked in the future.

A "want" in the Upper Coal at Farme Colliery, indicated on the one-inch map (Sheet 31), has been traced for over 1½ miles. Elaborate drawings of the sections of this "want" exposed in the workings have been kindly supplied by Mr. Anderson, of Farme, to whom we are also indebted for much other information.

It has been found possible, by means of "mussel bands" and other horizons, to correlate nearly all the coals within this area, between the Splint and Upper Drumgray, with their more important equivalents in other parts of the Clyde basin.

Red-stained, white and yellow sandstones with red shaly partings are exposed in quarries to the south and east of Rutherglen, and lie within 20 fathoms of the Upper Coal. They bear a close lithological resemblance to the sandstones in the area further to the east, some of which lie at a considerably higher horizon and have been included in the so-called "Red Sandstones" of the Middle (or Upper) Coal-measures.

Mr. Grant Wilson.

The Coal-measure area examined by Mr. Grant Wilson lies on both sides of the Clyde between Cambuslang and Bellshill (Sheet 31) and extends south to Hamilton (Sheet 23). A well-defined syncline enters the ground between Fullarton and Cambuslang, the axis of the fold passing S.E. by Hallside and Caldergrove to the west of Hamilton. The deepest part of the basin is found around Hallside Colliery. On the north side of this fold the beds dip S. and S.W. at 5° to 10°. The basin is crossed by several E. and W. faults, each with a downthrow to the N., with the result that the outcrops along the northern limb of the fold are shifted northwards in the direction of Coatbridge. The area is bounded on the south-west by the powerful fault which throws down the Coal-measures against the volcanic rocks of the Cathkin Braes and Dechmont Hill, and at Crossbasket (Sheet 23), brings strata more than 100 fathoms above the Upper Coal into contact with the Calciferous Sandstone.

The principal faults cross the area from E. to W. One of these extends from Carmyle to North Alderston, with a maximum downthrow to N. of 45 fathoms. Another, with a similar throw, has been proved to the south of Bothwell, and traced to Hamilton Palace Colliery. There are also several N. and S. faults. One of these, between Wester Daldowie and Loanend, is twice shifted by E. and W. faults, and it may therefore be inferred that the latter belong to a later system of dislocation.

In the Bent and Auchinraith fields the beds are lying flat and are practically untroubled by faults. The seams wrought in this district, with the exception of the Rosehall, Tannochside and Fullarton pits, belong to the upper group of coals that lie above the Airdrie Blackband Ironstone.

*General Section of Coal-measures Compiled from the Journals of Ten Pit Shafts in the Principal Collieries* within the Area between Cambuslang and Hamilton.*

| | Ft. | In. |
|---|---|---|
| Red and purple sandstones and fireclays passing downwards into white and grey sandstones and blue fireclays ... ... | 660 | 0 |
| White and brown sandstones, shales and fireclays, with from 9 to 16 thin coal seams ... ... ... ... ... ... | 430 | 0 |
| Coal, Gas, and Mussel-band Ironstone (Palace Craig) Hamilton and Bents ... ... ... ... ... ... ... ... | 1 | 11 |
| Strata ... ... ... ... ... ... ... average | 90 | 0 |
| Coal "Upper or Wandering" ... ... ... 9 in. to | 5 | 2 |
| Strata ... ... ... ... ... ... ... average | 59 | 0 |
| Coal and Mussel-band Ironstone ... ... ... ... ... | 1 | 6 |
| Strata ... ... ... ... ... ... ... average | 43 | 0 |
| Coal "Ell" ... ... ... ... ... ... 4 ft. to | 8 | 1 |
| Strata ... ... ... ... ... ... ... average | 23 | 0 |
| Coal and Mussel-band Ironstone ... ... ... 7 in. to | 1 | 0 |
| Strata ... ... ... ... ... ... ... average | 29 | 0 |
| Coal "Pyotshaw" ... ... ... ... ... 3 ft. 3 in. to | 4 | 10 |
| Strata ... ... ... ... ... ... ... average | 21 | 0 |
| Coal "Main"... ... ... ... ... ... 3 ft. 6 in. to | 5 | 6 |
| Strata ... ... ... ... ... ... ... average | 47 | 0 |
| Coal "Humph" ... ... ... ... ... 1 ft. 1 in. to | 3 | 0 |
| Strata ... ... ... ... ... ... ... average | 31 | 0 |
| Coal "Splint" or "Lady Ann" ... ... ... 3 ft. to | 5 | 9 |
| Strata ... ... ... ... ... ... ... average | 3 | 8 |
| Coal "Virgin" or "Sour Milk" ... ... ... 1 ft. 2 in. to | 2 | 9 |
| Strata ... ... ... ... ... ... ... average | 69 | 0 |
| Airdrie Blackband Ironstone and Coal ... ... 1 ft. 1 in. to | 2 | 3 |
| Strata ... ... ... ... ... ... ... average | 67 | 0 |
| Coal "Virtuewell," "Benhar," or "Wee Cleland" 5 in. to | 2 | 10 |
| Strata ... ... ... ... ... ... ... average | 52 | 0 |
| Kiltongue Oil shale and Mussel-band ... ... 5 in. to | 3 | 0 |
| Strata ... ... ... ... ... ... ... average | 42 | 0 |
| Coal "Kiltongue" ... ... ... ... ... 6 in. to | 5 | 10 |
| Strata ... ... ... ... ... ... ... average | 61 | 0 |
| Coal "Upper Drumgray" ... ... ... ... 1 ft. 4 in. to | 2 | 6 |
| Strata ... ... ... ... ... ... ... average | 54 | 0 |
| Coal "Lower Drumgray" ... ... ... ... ... ... | 2 | 8 |
| Total ... ... ... ... ... | 1,840 | 3 |

* Bogleshole, Orion, Westburn, Hallside, Bardykes, Viewpark, Bothwell Castle, Hamilton Palace, Whistleberry, and Bent Collieries.

Of the coals below the Airdrie Blackband horizon, the Kiltongue and Lower Drumgray are respectively 4 ft. and 2 ft. 8 in. thick at Rosehall Colliery, but thin to the westwards, and at Fullarton the former seam is only 2 ft. 4 in. The Kiltongue Mussel-band and shale occur at Bogleshole, but have not been worked in this area. In the same pit the Virtuewell is found in two thin seams, but thickens to 2 ft. towards the east. The Airdrie Blackband occurs as a 2 ft. coal of good quality at View Park, and has also been got at Greenfield and Bothwell Park.

The two lower coals of the Upper Group, the Splint and Virgin, like the Pyotshaw and Main higher in the series, often come together and are worked as one seam. The Humph, a thin coal of good quality, has been wrought to a limited extent only in the south-west side of the basin. At Tannochside it is absent. The Ell coal, the most extensively mined seam in the district, is rapidly becoming exhausted, and near Hamilton is quite wrought out.

### Carboniferous Limestone Series.

From the mining information and journals of bores obtained in the area between Banton and Denny, the following sequence of the coals in the Carboniferous Limestone Series below the Index Limestone has been established:— Dr. Cramptor

| | | | |
|---|---|---|---|
| Index Limestone | | about | 3 ft. 6 in. |
| Strata | | „ | 8 fathoms |
| Thin coals, one 2 ft. thick, known as the Garth Coal, and equivalent to the Twechar Coal of Kilsyth. | | | |
| Strata | | about | 22 fathoms |
| Upper Blackband Ironstone of Denny | Middle Possil or Gartshore position. | | 9 to 10 in. |
| Strata | | | 7 fathoms |
| Lower Blackband Ironstone of Denny | | | 9 to 10 in. |
| Strata with thin coals | | | 30 fathoms |
| *Steam Coal of Denny | Neilston position. Cloven Coal of Kilsyth. | | 2 ft. 8 in. |
| Strata | | | 8 in. to 8 fms |
| Main Coal (Bannockburn Main) | | | 1 ft. 3 in. |
| Strata | | | 6 to 8 fms. |
| Knot Coal | | | 1 ft. 6 in. |
| Strata | | | 5 to 8 fms. |
| Black Metals with Clayband Ironstone | | about | 12 fathoms |
| Strata | | | 8 to 12 fms. |
| Strata with Clay band Ironstones and Blackband Ironstone 6 in. to 11½ in. locally developed | Banton, Garscadden and Garibaldi position. | | |
| Strata | | about | 5 fathoms |
| Strata with thin coals locally developed | | | |
| Hosie Metals, largely black shales, with marine limestones (Hosies), and clayband ironstones | | | |

The distance between the Index limestone and the Black metals is the same as at Kilsyth, and, indeed, varies little between Balgrochan west of Kirkintilloch and Denny, a distance of 12 miles. The position and number of coals and ironstones present between these horizons, however, show great

* Worked at the present time.

variation, and the valuable coking coal of Kilsyth has not been found of a workable quality east of the large fault which forms the eastern boundary of the Banton coalfield. The only pits now working in the area south and west of Denny are those of the Herbertshire Colliery, where the steam coal is alone raised at present.

### CONTEMPORANEOUS VOLCANIC ROCKS OF CALCIFEROUS SANDSTONE AGE.

Mr. Anderson.

The Cathkin Hills, south of Rutherglen, are formed of contemporaneous volcanic rocks of Calciferous Sandstone age. This volcanic area is completely bounded on the north, east, and west, and to a certain extent on the south, by faults which in each case bring down higher strata. Along the northern face of the hills the lava flows are gently inclined towards the south. The different flows are sometimes separated by thin beds of ash, and on the south-western margin of the area there is an increase in the amount of fragmental material, which includes agglomerate, ashy grit, and fine mud, which is probably of volcanic origin.

There is a considerable diversity of rock types within the area. Such specimens as have already been examined under the microscope show that one of the most prevalent rocks is a basalt of the Dunsappie type.

### INTRUSIVE IGNEOUS ROCKS.

Mr. Wilson.

*Dolerite.*—Several of the coalfields within Mr. Wilson's area are intersected by dykes of dolerite, locally known as "whin gaws." Their general direction is E.S.E and W.N.W.; their breadth varies from a few inches to 90 feet, and they appear to be later than the fault movements. It is found in the workings that the amount of coal burnt and rendered useless on either side of these intrusions is in direct proportion to the breadth of the dyke.

In several of the collieries there are also considerable areas of 'burnt' coal, due to the intrusion of thin sills of 'white trap' either immediately above or below a seam.

### IGNEOUS ROCKS.

Dr. Crampton.

Two east and west dolerite dykes occur close together in the Herbertshire Colliery, near Denny, and have been proved in the steam coal and in the blackband ironstone formerly worked at a higher horizon. The coal in contact with these intrusions is burnt, and in the area between the two dykes consists almost entirely of ball-shaped masses, 2 inches to 1 foot in diameter, with a concentric or onion-like structure. Similar phenomena were observed in working the Main coal at Castlerankine, west of Denny; but in this case the presence of the igneous rock was not proved, the working being stopped at the face of the burnt coal.

The dolerite sill of the 'Riggin' at Kilsyth has been intruded

about the position of the Index limestone, but to the east and west of Kilsyth passes downwards to lower horizons. Eastwards it falls rapidly to the Black Metals, while a lower sill, intrusive in the Hosie Metals, is exposed at the surface. To the west of Denny the higher intrusion dies out, or joins the lower sill to form the great mass of dolerite between Denny and Stirling, which there overlies the volcanic rocks of the Campsie Fells.

## DRIFT.

Mr. Carruthe

The examination of the dritt deposits between Rutherglen and Bellshill has shown the existence of a series of unfossiliferous laminated clays and sands, interbedded with the boulder-clay, and occurring up to a height of 400 feet above sea level. It was not found possible to map them out in accurate detail during the limited time available for the revision. At more than one locality violent contortion of the finer deposits was observed.

A well-marked terrace, about 87 feet above O.D., is indicated on the existing map as a 100-feet raised beach. This feature has been traced to the east and west of Glasgow on both sides of the Clyde, and no evidence whatever of the marine origin of the terrace was found. Along its upper limit the sand and gravel merge into the boulder-clay. The evidence suggests that this terrace marks the limits of an ice-dammed lake, whose northerly margin, to the west of Glasgow, lay at Drumchapel.

Mr. Hinxman.

An excellent section of a boulder-clay 'drum,' now exposed in the quarry on the bank of the canal at Hamilton Hill slip, Glasgow, shows the great depth of this deposit. The total thickness of clay seen in the quarry face, and found in the excavation made for a barge dock at the foot, is at least 100 feet. The dark-grey clay contains numbers of well-glaciated boulders, some of large size. Besides those of local origin there are blocks of many varieties of Highland metamorphic rocks, and large rounded boulders of a red porphyritic granite, closely resembling that of the Garabol complex.

Dr. Crampton

The lower ground flanking the Campsie Hills to the east of Kilsyth is covered to a great depth with drift, and, with the exception of the protruding masses of dolerite, the rock is only exposed in the deep stream gorges. Remarkable evidence of the thickness of the glacial deposits is afforded by the operations at present being carried on at the Knowehead Pit, a mile west of Dennyloanhead. The pit is sunk on the side of a low hill, 100 feet below the summit, and passes through 93 feet of alternating layers of sand and gravel and boulder-clay before reaching the rock. A mine was driven into the hill from the pit-head for 372 feet before rock was touched beneath a cover of drift 192 feet in thickness.

The bores put down along the vallevs of the Kelvin and the Bonny water show the great depth of drift along the course of the pre-glacial channels first described by Dr. Croll.* Sand

* *Trans. Edin. Geol. Soc.*, vol. i., p. 330.

and gravel also lie thickly over the higher ground between Kilsyth and Denny, with numerous boulders derived from the igneous rocks of the 'Riggin.' Striæ observed to the N.W. of Denny point to the confluence of two ice-streams, coming from the N.W. and W.S.W. on the eastern side of the dolerite mass that flanks the Campsie Hills. Fine marginal channels are also visible on the hill sides in this region.

## ECONOMICS.

r. Wilson. *Coal.*—At the time of the original survey, 36 years ago, working collieries in the ground west of Cambuslang were few, and the Uddingston, Bothwell and Hamilton fields were untouched. After the year 1870, a great development took place, and 68 shafts are now working within this area. Competent authorities agree that the present output will be maintained, but not much increased, for some years; the only unexploited fields being that of Holm, N. of Uddingston, and the troubled belt along the Dechmont Hill boundary fault. Several of the coal companies are preparing to put down bores to test the coals below the Virgin position, and though the evidence already obtained tends to show that these lower seams may not be so thick as in the New Monkland and Slamannan fields to the N.E., the introduction of coal-cutting machinery will enable them to be profitably worked.

The following seams are at present worked between Cambuslang and Hamilton: the Upper and the Ell coals, both good household coals; the Pyotshaw, chiefly used for furnace and manufacturing purposes; the Main, either as a second class household or as a steam coal. The Humph is thin and little worked, but is of good quality, and with the introduction of coal-cutting machinery will be further developed. The Splint, the principal furnace coal of Lanarkshire, is rapidly becoming exhausted. At Uddingston it contains a band of gas coal. The Virgin is, at its best, a good household coal.

The household coal raised in this district is prepared for the market by dressing machinery. The appliances used vary at the different collieries to suit their respective requirements, and may be classed as 'wet' and 'dry' processes. The former includes washing out (by the Lurig method) of the smaller class of coal from the dross ('gum') and its separation into various grades. The 'dry' process includes 'table-picking' 'riddling,' 'screening,' and 'jiggering' plants.

r. rampton. The coals chiefly wrought in the Livingston field are the Splint, raised for manufacturing purposes; and the Upper and Lower Drumgray and Ball coals, for household use. In the Banknock field the output is mostly from the Splint, Ladygrange, and Banknock Main seams. The Ladygrange is a good house coal; the others are manufacturing, steam, and gas coals. The oil shale above the shale coal was worked for a time at Coneypark, but this coalfield has been temporarily abandoned.

The statement in last year's SUMMARY that the Blackband ironstone is now being worked at Kilsyth is erroneous.

*Building Stone.*—The sandstones belonging to the so-called 'Red Sandstone group' that forms the upper part of the Coal-measures, are largely quarried around Uddingston, and supply an excellent and durable building stone. In the Bothwell Park and Bell Quarries, east of Uddingston, a greyish-white sandstone with streaks of red is raised. The stone is easily quarried and large blocks can be obtained, but irregular concretionary masses occur in places and increase the cost of production. A large quarry is also worked at Bredisholm, N. of Uddingston, in a striped red and purple sandstone. Both this rock and the sandstone of Bothwell Park are found, under analysis, to contain a large proportion of carbonates. Other quarries have recently been opened at Hallside, Newton, and Homehill, near Cambuslang, the former in the red sandstones above the Upper coal, the latter in a yellow or grey freestone at a much lower horizon, immediately above the Humph coal. The Homehill stone is of excellent quality, and is used for all kinds of dressed work; the débris being ground down into building and plastering sand. All the more modern houses in and around Cambuslang are built of stone from this quarry; those of Uddingston, Bellshill, and Motherwell from Bothwell Park and Bell Quarries; while the Bredisholm Quarry has supplied material for several important buildings in Glasgow. Mr. Grant Wilson.

A building stone of inferior quality is raised in the Eastfield Quarry, between Rutherglen and Cambuslang. The rock is a good freestone, but its appearance is disfigured by irregular splashes of red oxide of iron. It is used locally for inside building work. Mr. Carruther

The freestone quarried on a large scale near Dullatur Station, on the Glasgow and Edinburgh N.B. Railway, affords a building stone of good quality, especially adapted for fine dressed work, mouldings, &c., for which an extensive sawing and dressing plant has been set up. This sandstone lies a short distance beneath the Index limestone, and therefore corresponds in position to the Cowlairs sandstone of the Glasgow district. Dr. Crampton.

*Brick Clays.*—Plastic bricks of good quality, used for the better class of building work, are made from the laminated glacial brick-clays on the south side of the Clyde, west of Rutherglen. In the Uddingston district, machine-made composition bricks have supplanted the hand made bricks from the brown plastic clays alone that were at one time worked throughout the district. The 'tirr' or covering at the Hamilton Palace Quarry, is composed of brick clay and red boulder-clay. The two deposits are ground up together in a 'pug' mill for the manufacture of ordinary red wire-cut bricks, which are burnt in cone kilns. Blaes from pit refuse heaps is also ground up for bricks, used chiefly for inside work. A more economical method of burning in tunnel kilns Messrs. Hinxman, Grant Wilson, an Carruther

enables these bricks to compete successfully in this class of work with the laminated clay bricks, which are still to a large degree burnt in the old wasteful "clamp" kilns.

*Fireclay.*—A red mottled fireclay which covers the sandstone at Hallside Quarry, Newton, is used for making red wire-cut plastic bricks.

Messrs. Hinxman and Anderson.

*Road Metal and Pavingstones.*—The dolerite sills and dykes supply most of the road metal used in the district. The rock is crushed into material of five graded sizes, and the larger fragments are also used for concrete blocks. Kerbs and paving setts are turned out from the dolerite quarries of Firpark and Garteraig in the suburbs of Glasgow. The basalt of the Cathkin Hills is quarried on a small scale near Carmunnock for road metal by the Lanarkshire County Council.

## II.– PALÆONTOLOGICAL WORK.

Dr. Crampton.

The Palæontological Department in Scotland has been carried on under the general supervision of Dr. Kitchin, by Messrs. Crampton and Carruthers, and by the fossil collectors, Messrs. Macconochie and Tait. Valuable assistance has been rendered by the following specialists: Dr. Traquair, Mr. Kidston, and Dr. Wheelton Hind, who have determined the fishes, the plants, and the lamellibranchs respectively.

The total number of fossils collected during the year and entered in the Survey list books amounts to 1,224. Of these Mr. Macconochie collected 188 from the Carboniferous formation, and Mr. Tait 1,036, partly from the Carboniferous rocks and partly from the Old Red sandstone of Caithness.

A feature in the fossil collecting has been the careful examination of the cores of deep bores, with the view of recording accurately the horizons at which different species of fossils occur. Although the amount of material thus obtained at any one horizon is small, the greatest accuracy of position in reference to well-known horizons tends to compensate for this deficiency. The deep Burnlip bore, to which reference has been made (p. 92), commences at the base of the Coal-measures and is intended to prove the Lower limestone coals. Although the bore has not yet reached the Index limestone, a great amount of fossiliferous material has been collected and examined, and a horizon in close relation to the Calmy limestone, important from the palæontological point of view, has been detected. In this connection the following note from Dr. Wheelton Hind is of interest.

Dr. W. Hind.

"The discovery of shales with *Edmondia punctatella* (Jones) in abundance in the bore hole at Burnlip by Mr. D. Tait, is of great interest and importance. It occurs here below the Calmy limestone and was the object of special search by Mr. Tait, because this shell had been recorded from the shale below the Calmy limestone at Linn Spout, Dalry; Thornliebank, Renfrewshire; and S.E. of Glenboig, 8 miles E.N.E. of

Glasgow; and had also recently been found by himself at Chryston, 6 miles N.E. of Glasgow in the same horizon. The distance between Linn Spout and Chryston is about 28 miles in a N.E. and S.W. direction. An important paper by Mr. Neilson (*Trans. Geol. Soc. Glasgow*, Vol. xii., pt. iii., p. 294) deals with the section containing *Edmondia punctatella* at Davieland, Thornliebank.* He shows that a bed of shale with *Actinopteria persulcata* (M'Coy) intervenes at that locality in beds containing *Edmondia punctatella*. Mr. Tait has obtained this species at Burnlip associated with *E. punctatella* but never in the same laminæ."

This shale with *Edmondia punctatella* intervenes between the Calmy limestone and the closely underlying Hirst coal. It was analysed by Mr. Steuart, of Broxburn, who reports that it yields 13½ gallons of oil and 6.2 lbs. of sulphate of ammonia per ton of shale. In view of the doubt which exists as to the environment in which *Edmondia punctatella* lived, the above analysis, proving the rock to be an inferior oil-shale, seems important, as the species usually found in oil-shales have been generally considered to have been of fresh water or brackish origin.

The fossils collected by Mr. Tait from the new pit shaft at Bedlay† have also proved of interest, but, unfortunately, the work was not commenced until the sinking was far advanced. Limestones, containing marine fossils, were detected in the horizon of the 'Black Metals,' about 80 fathoms beneath the Index limestone. The amount of material is very small and badly preserved, but is sufficient to indicate marine conditions at this horizon. The forms determined are *Productus sp.*, *Camarophoria sp.*, *Chætetes dubius* (McCoy), and a lamellibranch not yet named.

Plants have been collected by Mr. Tait with the view of determining the age of the group of red sandstones overlying the Lower Coal-measures round Uddingston, Lanarkshire. These have been named by Mr. Kidston, who has referred them to the Lower Coal-measures above the Millstone grit.

A number of brachiopods, corals, and other marine forms have been collected from the Carboniferous Limestone and Calciferous Sandstone series, and also from the marine zones in the Millstone grit, in continuation of the work done last year and referred to in the SUMMARY OF PROGRESS. Further specimens of lamellibranchs have been examined by Dr. Wheelton Hind. The brachiopods have been determined by Dr. Crampton, and the corals are in course of examination by Mr. Carruthers. A number of brachiopods from the limestone at various horizons have been determined and help to confirm the opinion that several species have a very wide distribution in time from the upper part of the Calciferous sandstone series

* See also papers by J. Young and Prof. T. R. Jones, *Trans. Geol. Soc., Glasgow*, vol. ii., pp. 71, 72; vol. ix., p. 79; and a recent paper (1906), by Peter Macnair, on "The Geology of the Rouken Glen and its Neighbourhood."

† See p. 100.

to the Millstone grit. The species *Productus latissimus* J. Sowerby, which, until lately, has been considered as possibly marking a zone in the Upper limestone group, has been found in abundance in the Hollybush limestone, the lowest limestone as yet definitely determined in the Glasgow area, and lying at least 40 fathoms beneath the Hurlet limestone, which is taken as forming the base of the Carboniferous Limestone series. *Orthotetes crenistria* (Phillips) is also abundant in this limestone, and appears to be indistinguishable from the *Orthotetes* occurring at higher horizons, as high up as the marine bands of the Millstone Grit. Several other forms as brachiopods have the same wide distribution in time in the Scottish Carboniferous rocks, but it is hoped that some forms may yet be found which may be of zonal value.

There seems to be evidence to prove that the disappearance and reappearance at successive horizons of those forms which have a wide distribution in time is due to rapid change of conditions, and in this connection the careful study of the cores of deep bores should prove valuable.

Mr. Carruthers.

Through the courtesy of Messrs. Baird and Co., Ltd., various highly fossiliferous horizons met with during the recent sinking of the Pollok Pit, at Corkerhill, 3 miles S.W. of Glasgow, have been examined and a considerable number of specimens obtained. These horizons, occurring some distance above the top Hosie limestone, are not exposed, to our knowledge, at any other locality in the Glasgow district, and it was therefore important for zonal purposes that they should be thoroughly investigated during the short period in which they were accessible.

The morphological examination of various Rugose corals, to which reference was made in last year's SUMMARY (p. 141), has now been concluded, and the results of the investigation have been published in detail.* It was shown that the Rugosa are to be considered as primarily hexamerous, like most of the Anthozoa, and not tetramerous. Most of the specimens examined were from the collection of the Geological Survey of Scotland, though additional ones were obtained from the Museum of Practical Geology in London, and from Mrs. Gray's well-known private collection from the Girvan district.

An examination of the distribution of corals in the Scottish Carboniferous limestones is now in progress, special attention being paid to any evidence bearing on the sequence of corals established by Dr. Vaughan in the Bristol area, and since extended by him and other workers to various parts of Great Britain. The table of comparative vertical sections, illustrating the positions of the various limestones in Scotland and the north of England, prepared by the late Mr. Gunn,† shows that in all probability most of the Scottish horizons, rich in corals, lie above those investigated lately in England. Yet it would appear that certain genera occur side by side in the same band

* *Ann. and Mag. Nat. Hist.*, Nov., 1906.
† *Geol. Mag.*, 1898, vol. v. (new series), p. 348.

of limestone in Scotland, some of which are restricted to low zones and others to high zones in the Bristol area. For example, the genera *Zaphrentis* and *Amplexus* undoubtedly occur in Scotland in association with *Lithostrotion junceum* (Flem.) and *Dibunophyllum*. At the same time, it is hoped that certain broad zones, at any rate, may be identified in Scotland with the help of the corals.

In the course of the field-work last year, a large number of fish remains from the Old Red Sandstone of Caithness was collected and referred to Dr. Traquair for determination, who has furnished the following report:—

Dr. Traquair.

"I have carefully examined a large number of fossil fishes and fish remains collected in Caithness during the past year by the Geological Survey of Scotland, and the result is embodied in the following list of localities with the species obtained from each. Some of the specimens, owing to fragmentary condition or deficient preservation, were not specifically determinable.":—

SPECIMENS COLLECTED BY MESSRS. CRAMPTON AND CARRUTHERS.

*Thursius* sp. Girston Cliff Top, lower part of Wick Beds.
*Thursius* sp. Second Limestone in Wick Beds.
*Thursius* sp., *Osteolepis* sp. } Third Limestone in Wick Beds.
*Thursius* sp. First Papigoe Beds.
*Dipterus Valenciennesii.*, *Coccosteus decipiens.* } Field Beds.
*Glyptolepis* sp., *Dipterus* sp. } Ackergill Beds, Ackergill.
*Glyptolepis* sp. Ackergill Beds, Keiss.
*Thursius pholidotus.* Kilns, Nybster, Castle Sinclair Beds.

SPECIMENS COLLECTED BY MR. TAIT.

*Dipterus macropterus.*, *Coccosteus decipiens.*, *Thursius macrolepidotus.* } Shore at Papigoe, N.E. of Wick.
*Homosteus Milleri*, detached plate. Scarfskerry, E. of Thurso.
*Thursius macrolepidotus*, small specimen. Achunabust, 7½ miles S.W. of Thurso.
*Coccosteus decipiens.* Noss Head.
*Coccosteus decipiens.* Skyoll, ½ mile S. of Noss Head.
*Glyptolepis paucidens.*, *Thursius pholidotus.* } Skirsa Head.
*Dipterus Valenciennesii.*, *Coccosteus decipiens.* } Selkie Head.
*Coccosteus decipiens.*, *Thursius* sp. snout., *Dipterus*, scales. } Between Castle Sinclair and Ackergill Tower.
*Dipterus Valenciennesii*, cranial roof. Forss Bay, S. of Nybster.
*Homosteus Milleri.* Shore, a little S. of the Baptist Chapel, Nybster.
*Thursius pholidotus*, cranial shields, &c., *Glyptolepis paucidens.* } Samuelsgoe, Auchengill.
*Thursius pholidotus.* Biel of Duncansby.
*Glyptolepis paucidens.* Brough Head, Nybster.
*Thursius macrolepidotus.* South Head, Wick.
*Palaeospondylus Gunni.*, *Dipterus Valenciennesii.*, *Pterichthys Milleri.*, *Mesacanthus* sp. } Achanarras.
*Dipterus Valenciennesii.*, *Coccosteus decipiens,* } Banniskirk.

# III.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

## A. ENGLAND AND WALES.

### I.—Maps.

*(a) Twenty-five Miles to One Inch.*

Map of the British Islands. Price, colour-printed 2s.; uncoloured, 1s.

Uncoloured copies are also supplied of an Index Map on this scale, showing the sheets of the four-mile and one-inch scales, with particulars of memoirs, maps, sections, &c., printed on the back. Price 1s.

*(b) Four Miles to One Inch.*

New Series; Drift Edition; colour-printed.
Sheet 8 (Flamborough and Spurn Heads), price 2s.
Sheet 12 (Parts of Lincolnshire and Norfolk), price 2s. 6d.

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## *LIST OF EXTRA OFFICIAL PUBLICATIONS.*

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————————and O. T. JONES.—Note on the Discovery of Prehistoric Hearths in South Wales. *Archæologia Camprensis*, ser. vi., vol. vi., pp. 17-34.

GIBSON, W.—Marine Beds in the Coal-measures of Yorkshire. *Naturalist*, April, 1906.

HILL, J. B.—The Older and Newer Palæozoics of West Cornwall. *Geol. Mag.*, pp. 206-216.

LAMPLUGH, G. W.—Report on an Investigation of the Batoka Gorge and adjacent portions of the Zambesi Valley. *Rep. British Assoc.* for 1905, pp. 292-302.

————————On British Drifts and the Interglacial Problem (Presidential Address to Section C, British Association, York). *Rep. Brit. Assoc.* and *Nature*, vol. lxxiv., No. 1920, pp. 387-400.

————————Notes on the Occurrence of Stone Implements in the Valley of the Zambesi around Victoria Falls. *Journ. Anthrop. Inst.*, vol. xxxvi., pp. 159-169.

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————————Report on Plant-remains from the British Village at Glastonbury. *Proc. Somerset Arch. and Nat. Hist. Soc.*

————————Coast Erosion. *Journ. Roy. Geogr. Soc.*, vol. xxviii., pp. 487-495.

SMITH, B. (and R. H. RASTALL).—Turns on the Haystacks Mountain, Buttermere, Cumberland. *Geol. Mag.*, pp. 406-412.

THOMAS, H. H.—On an Epidote from Inverness-shire. *Min. Mag.*, vol. xiv., pp. 109-114 (1905).

USSHER, W. A. E.—Geology of Devon. *Victoria History of the Counties of England.*

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————————(with G. W. YOUNG).—Excursion to Lyme Regis, Easter, 1906. *Proc. Geol. Assoc.*, xix., pp. 320-340.

# APPENDIX.

## I.—The Scapolite-bearing Rocks of Scotland.

By John S. Flett, M.A., D.Sc.

Although scapolite-bearing rocks occur in several parts of the Scottish Highlands they are by no means common there, and are very rare in the rest of Britain. References to some of these occurrences are scattered through the literature of British petrography, principally in the Annual Reports and Summaries of Progress of the Geological Survey, while others, though known for some time, have not yet been described. It has seemed worth while to prepare a general account of these rocks and of their mode of occurrence and probable geological significance; they present considerable variety, and show some features of interest. Many of them are, without doubt, metamorphosed sediments; others are metamorphic igneous rocks, and there is a small number which, in the present state of our knowledge, cannot be definitely assigned to either of these groups. Some of them belong to the orthogneisses and paragneisses of the Lewisian; others occur with the limestone and black schist of the Dalradian or rocks of the Southern and eastern Highlands; a few have been found as pebbles in the 'boulder-bed' or conglomerate schist of Schichallion.

### I.—Scapolite-bearing rocks of sedimentary origin.

*Contact-altered limestones, calc-silicate rocks, and gneisses with with scapolite, in the Dalradian or Central Highland Series.*

The Upper Deeside district, represented on Sheet 65 of the Geological Survey's one-inch map of Scotland, is flooded with intrusions of gneiss, diorite, granite, porphyry and pegmatite. They form nearly one-half of the surface of the country, and may readily be believed to underlie the sedimentary schists in a considerable portion of the remainder of the area. Hence it is not to be wondered at that metamorphism of a thermal type is of great prevalence in this region, and that the Highland schists very often contain minerals which are regarded as produced by the contact action of the intrusives. The country rocks which have been invaded by the granite and other igneous intrusions are the black schist, limestone, and quartzite of the Central Highland series, which extend south-eastwards into Perthshire and Argyllshire. The Moine granulites also enter into the north-east corner of this sheet, but are not of a nature to show thermal metamorphism very obviously. The quartzite is frequently baked, and to a large extent recrystallized. The black schist or phyllite is often converted into biotite hornfels or into cordierite, andalusite, and sillimanite gneisses. The limestones are converted into marbles and various types of calc-silicate rocks containing malacolite, diopside,

wollastonite, tremolite, epidote, zoisite, garnet, vesuvianite, sphene, various felspars and quartz. Scapolite also occasionally appears along with the other crystalline silicates.

On the north side of the River Dee, near Balmoral, there is a small area of Highland schists resting on extensive masses of granite and diorite. Small patches of the black schist, limestone, and quartzite are sometimes completely surrounded by the igneous rocks. These show extensive alteration. Crathie, Creag Mor, and Leac Gorm are mentioned by Heddle* as localities for wollastonite, malacolite, garnet, vesuvianite, epidote and actinolite. At Creag Bheag and Creag an Ordaich (two and a half miles, and two miles west of Balmoral) Mr. E. H. Cunningham Craig observed recrystallized quartzite and black schist converted into cordierite, andalusite and sillimanite gneisses, with biotite, quartz, various felspars, iron oxides, rutile, zircon and tourmaline.† The limestones also share in the general metamorphism.

The altered limestones from Creag Bheag and Creag an Ordaich proved on microscopic examination to contain grains of colourless scapolite, in some cases fresh, in others weathered to dense aggregates of fine-grained mica and other secondary minerals. They varied in size up to one or two millimetres in diameter. In some of the rocks scapolite is abundant, in others scarce; occasionally it showed traces of octagonal outlines, but this was unusual. The other minerals were wollastonite, green diopside, brown garnet, sphene, vesuvianite, iron oxides, pyrites and untwinned alkali felspar. Calcite varied greatly in abundance and was sometimes nearly completely absent; in that case the original limestones must have been highly impure. Of these minerals only the sphene forms well-defined crystals, yielding small sections pointed at both ends. The rocks are somewhat banded and all their ingredients are about equidimensional, but the garnet, and sometimes also the vesuvianite, are in large crystals with irregular boundaries, filled with grains of augite, calcite, pyrite and other ingredients of the rock. The garnet is pale-brown in section and usually isotropic. Felspar is mostly confined to certain bands and has the low refractive index of albite or orthoclase. It is mostly quite homogeneous and untwinned, but may have the characters of microperthite or cryptoperthite. Quartz and epidote were not observed. One of these limestones is represented on the Plate, Figure 1.

About twelve miles south-west of Balmoral, in the Forest of Glen Ey, black schist and limestone come in contact with intrusive felsite and are hornfelsed at the junction. This area was mapped by Mr. E. H. Cunningham Craig,‡ and among the specimens from this locality is one which Dr. Teall§ has

* Heddle, M. F.—The Mineralogy of Scotland, 1901.

† E. H. Cunningham Craig.—Summary of Progress of the Geological Survey for 1900, p. 21 (1901).

‡ E. H. Cunningham Craig.—Summary of Progress of the Geological Survey for 1899, p. 35 (1900).

§ J. J. H. Teall, *ibid.*

described as follows; "The specimen contains a band of dark purplish hornfels between bands of grey and pale-green hornfels. The dark purplish hornfels owes its colour to the presence of minute scales of biotite. The other constituents are granules of pyroxene and a colourless mineral, the grains of which are too small for precise identification. They are probably either quartz or felspar. The grey bands are devoid of biotite but richer in pyroxene. They also contain grains of the colourless mineral and large individuals of a mineral belonging to the scapolite group (dipyre). The scapolites are crowded with inclusions of pyroxene in the form of minute grains. The grains in the scapolite are distributed in exactly the same manner as in the rest of the rock, so that the outlines of the crystals can only be distinguished in polarised light. Similar rocks have been described from the Pyrenees as 'cornéennes compactes' by Professor Lacroix. They are there regarded as Lias altered by contact with lherzolite."*

In other parts of Deeside scapolite occurs in the altered limestones, as at Gillan, two and a half miles south of Banchory, where Mr. Barrow has mapped a calc-silicate rock consisting of scapolite, green diopside, sphene, alkali felspars, pyrite, vesuvianite, and apatite. On the south side of the great Deeside granites, in Glen Effoch in Forfarshire, Mr. Barrow has traced a scapolite-bearing limestone within the boundary of his sillimanite aureole†. The last-named rock contains, in addition to scapolite, pale-green diopside, dark-green hornblende, sphene, calcite, and quartz. Both of these localities are in Sheet 66 of the Geological Survey's one-inch map of Scotland.

The only other occurrence of scapolite-bearing rocks in association with the Central Highland limestone, black schist, and quartzite, at present known, is in Glen Meran, one of the tributaries which enter Glen Lyon in Perthshire from the north. This area lies on the north edge of Sheet 46 of the Geological Survey's one-inch map of Scotland, and was mapped some years ago by Mr. J. S. Grant Wilson. The calc-sericite schist or Ben Lawers schist is present also in this quarter, and the rocks are penetrated by epidiorites, while a short distance to the north a mass of 'newer' or non-foliated diorite makes its appearance, probably an offshoot of the great Moor of Rannoch granite and diorite. The scapolite-bearing rocks occur as lenticular outcrops or long, narrow bands, generally in the black schist, but sometimes in contact with the quartzite.

The more calcareous rocks from this locality may be described as impure crystalline limestones or cipolins. They are foliated, and contain, in addition to much calcite, grains of quartz, yellow or green biotite, epidote, sphene, apatite, iron ores, and a few crystals of plagioclase felspar. Pale-green

* Etude Minéralogique de la lherzolite des Pyrenées et de ses phénomènes de contact. Nouvelles Archives du Museum d'Histoire Naturelle, 3rd ser., pp. 209-302.

† Barrow, G.—On an Intrusion of Muscovite-Biotite Gneiss in the South-East Highlands of Scotland. *Quart. Journ. Geol. Soc.*, vol. xlix., p. 330 (1893).

pyroxene and bright-green, fibrous amphibole (probably secondary) also are present. The epidote is clear yellow and pleochroic; none of these minerals shows good crystalline outlines.

In other specimens, bands rich in carbonates alternate with others which consist of crystalline silicates and quartz. Scapolite appears in these rocks, often in great plenty, and with it there is usually much pale-green pyroxene. The rocks which contain most scapolite, however, are nearly free from calcite, and may be described as banded scapolite pyroxene rocks. They are greyish-green in colour, and have often much of the appearance of calc-silicate hornfelses. When biotite and hornblende are present in considerable quantity the foliation is always more pronounced.

The scapolite is always in large shapeless crystals, which become cloudy and semi-opaque on decomposition, and are replaced ultimately by dense aggregates of fine micaceous secondary products which have strong birefringence. Its cleavage is well marked in the freshest crystals, and it encloses grains of all the other ingredients of the rock. The foliation is often clearly traceable by the disposition of these enclosures in the scapolite, though this mineral itself takes no part in it. From this we may infer that the scapolite has developed after the parallel structure was stamped upon the rock. The pyroxene, which is next in abundance to the scapolite, is pale-green or greyish-green in colour in thin section, and very often shows idiomorphism in the cross sections. These are generally bounded by the two vertical pinakoids, the ortho-pinakoid usually greatly predominating, while the prism faces are very small or absent. The crystals are elongated parallel to the prism axis, and their extinction angle on the clinopinakoidal face is about forty degrees. Subradiate groupings of these crystals of pyroxene in a matrix of scapolite are very frequent, and are represented in the photographic Plate, Figure 3. The other ingredients of these rocks are quartz, felspar, yellow epidote, zoisite, garnet, vesuvianite, sphene, rutile and iron ores, muscovite and green actinolite or uralite.

The epidote is in rounded grains, and has a yellow colour and distinct dichroism; zoisite is far less common. The felspars are much weathered, but are mostly untwinned alkali felspar. Quartz is often common in those bands which contain least scapolite. Garnet is present in some quantity in several slides as irregular crystals of green and greenish-brown colour, and usually shows weak, anomalous double refraction. Only a few small grains of brown vesuvianite were observed. The biotite is reddish-brown and strongly dichroic; muscovite is far less common than brown mica. Actinolite, though frequent in the rocks containing no scapolite, appears seldom with scapolite and augite; it may be sometimes a secondary product replacing pyroxene. Sphene forms small spindle-shaped crystals; rutile occurs in fox-brown prisms, apatite in rounded grains; iron ores are scarce.

It seems safe to assume that the scapolite-bearing limestones of Glen Meran are contact-altered sediments; and the balance of probability inclines also to the view that the pyroxene scapolite rocks are of the same class. Their resemblance in structure and in mineral constitution to calc-silicate hornfelses is certainly very close. With them there are other gneisses which consist of quartz, felspar, epidote, green augite, hornblende, biotite and muscovite, with garnet, sphene, and other accessories like those of the rocks above described. These rocks do not contain scapolite. It is impossible to say whether these are all sedimentary or not; some of them may conceivably be older foliated igneous intrusions. If so, they are hardly of the same type as the other early intrusive igneous gneisses of this area. They are very diverse, scarcely any two specimens having the same constituents, and their exact origin in any case, may, for the present, be left an open question.

*Scapolite-bearing sedimentary gneisses, limestones, etc., associated with the Lewisian rocks of the Scottish Highlands.*

In the area of Lewisian gneiss which lies to the west of the Moine thrust-plane, there are, besides the typical orthogneisses which form the preponderating and best known types, a limited series of gneisses and schists which present the characters of altered sediments. They include kyanite schists and mica schists; a scapolite-bearing mica schist which occurs half a mile east of Fraoich Eilean, on Loch Gairloch, is probably one of the members of this series. At any rate, there is no reason to doubt that it was originally a sedimentary rock.

As will be seen from the photograph, Figure 4 of Plate, it carries small porphyroblastic crystals of scapolite which have rounded outlines with little trace of crystalline boundaries. They are very fresh, and show their cleavage well. For the most part they are quite free from enclosures of the matrix, and the foliation of the mica schist can be seen to wind around them in sinuous curves. The fine dark matrix of the rock consists mainly of biotite, quartz and felspar, with a small amount of carbonates, pale-red garnet, pyrite and iron oxides, sphene and zircon. In the hand specimen this is a very fine-grained, banded dark schist, having very much the appearance of a biotite hornfels, and showing occasional larger crystals of scapolite, garnet and pyrites. Although this rock contains no augite, it has a very few small pleochroic crystals of dark green amphibole.

The occurrence of scapolite in the Tiree marble, which is presumably part of the Lewisian, was recorded by the late Professor Heddle,* and this rock was subsequently investigated by Mr. A. K. Coomáraswámy.†

At Cnoc na h'Ula, about half a mile north of Laxford Bridge, Sutherlandshire (in Sheet 107 of the Geological

* Heddle, M. F.—Mineralogy of Scotland, 1901.

† Coomáraswámy, A. K.—Observations on the Tiree Marble, with Notes on others from Iona. *Quart. Journ. Geol. Soc.*, vol. lix., p. 91 (1903).

Survey's one-inch map of Scotland) there is a peculiar scapolite epidote rock associated with the Lewisian gneiss. This occurrence has been recorded in Heddle's Mineralogy of Scotland; the area was mapped by Mr. C. T. Clough. The hand specimens are granular crystalline, scarcely foliated; they show rounded white spots of scapolite, which may be a quarter of an inch across, in a matrix consisting mainly of greenish-yellow epidote. In the white spots little epidote is present; the remainder of the rock consists almost entirely of that mineral. The epidote is bright yellow and pleochroic in thin section, seldom twinned and with few signs of cleavage. The only other ingredients are small, lozenge-shaped crystals of sphene, apatite, quartz and a little plagioclase felspar which seems to be albite. There are no carbonates; a few dark-green crystals of hornblende are visible in the section.

Epidosite bands are known to occur with some frequency in the hornblendic and pyroxenic orthogneisses, but it seems in every way more likely that this is a metamorphosed limestone. In the rocks of the Lewisian inliers epidote is often very common in the limestones; no similar epidote scapolite rock has yet been found in any other part of Scotland.

In the country east of the Moine thrust-plane, inliers of Lewisian rocks occur, folded together with the Moine gneisses and schists, which they are believed to underlie unconformably. The rocks of these inliers may be divided into two groups, viz.: orthogneisses of intrusive origin (with amphibolites, eclogites, peridotites, &c.) and sedimentary paragneisses with marbles and calc-silicate rocks. In these latter scapolite is now known to occur with considerable frequency; in fact, they are the principal scapolite-bearing rocks of the British Isles. An account of the petrography of some of these inliers was given in the SUMMARY OF PROGRESS* for last year, and reference may be made to this for an account of the scapolite pyroxene hornblende gneiss of Allt Coire Dubh, near Scardroy.

It should be noted also that Professor Heddle† had previously recorded the occurrence of scapolite in the limestone of Gortally on Loch Ness, and had published an analysis of the mineral. This limestone is a member of a series of rocks which form an isolated inlier of the Lewisian. With it occur kyanite gneisses and muscovite schists.

In Sheet 115 of the Geological Survey's one-inch map of Scotland areas of Lewisian are shown outcropping among the Moine gneisses east of the Kyle of Tongue. The relations of the two sets of rocks to one another are not perfectly understood. The petrographical characters, however, of this area of Lewisian rocks are identical with those of the Lewisian inliers among the Moine gneisses further to the south. They include biotite gneisses, hornblende schists and hornblende gneisses, pyroxene gneisses and garnet amphibolites. There

* Flett, J. S.—On the Petrographical Characters of the Inliers of Lewisian Rocks among the Moine Gneisses of the North of Scotland. Summ. Prog. Geol. Surv. for 1906, p. 155 (1907).

† Heddle, M. F.—The Mineralogy of Scotland, vol. xi., p. 53, 1901.

are also calc-schists rich in pale-green pyroxene and hornblende, with brown, strongly pleochroic biotite, apparently metamorphosed calcareous sediments. Finally, there are scapolite pyroxene zoisite rocks, which also are to be regarded as altered limestones. The best example of these comes from the burn east of Creag Garbh, one mile north-north-west of Armadale, and is represented in thin section in Figure 2, of Plate. The commonest mineral in the slides is pale-green or colourless augite, (malacolite or coccolite) with optic axial angle (2 E.) 110 degrees, and extinction Z:c about 40 degrees. It shows the usual prismatic cleavage but is devoid of crystalline outlines and is nearly free from enclosures. Scapolite also is very abundant and in good preservation. It has occasionally traces of crystalline outlines, but very generally it fills up the interspaces between rounded grains of augite and zoisite. Decomposition begins along the cleavages and results in the formation of fibrous or lamellar micaceous aggregates. The abundant zoisite of these rocks is in large, irregular, colourless grains which polarize in grey and grey-blue colours, and often have a streaky appearance in polarized light. Small grains of this mineral may be practically isotropic, and then on account of the high refractive index might be mistaken for garnet. The zoisite often forms vermicular or myrmekitic intergrowths with a highly refracting mineral which seems to be muscovite. This peculiar 'micropegmatite' simulates an interstitial groundmass over a considerable portion of a section, lying between the other minerals. The subradiate, curved or club-shaped fibres are inferred to be zoisite from their similarity in optical properties to adjacent larger crystals of that mineral. They are themselves too small for accurate determination. The material in which they lie seems to be a secondary aggregate of fine micaceous substances. Small rhombs of sphene, grains of apatite and irregular masses of iron oxide and pyrites are the remaining ingredients of this rock. Hornblende is not present but a little green chlorite may be found here and there.

In other specimens from this locality scapolite is very abundant along with pyroxene, which is of pale-green colour. Quartz and calcite both occur in these rocks in some amount, and green amphibole fringes the pyroxene but is never conspicuous. Neither felspar nor zoisite was observed in the sections. These rocks are banded and rather coarsely crystalline. There can be no doubt that they are metamorphic limestones.

Last year some interesting scapolite-bearing rocks were mapped by Mr. E. M. Anderson in one of the Lewisian inliers at Allt-Garbh-Coire, about a mile south of Monar Lodge, Inverness-shire. One of the specimens contains a little calcite and is rich in graphite,* which occurs in bright grey crystal-

* A Scapolite Pyroxene Gneiss, rich in graphite, from Rawdon, Canada, has been described by Prof. F. D. Adams. The Geology of a portion of the Laurentian Area lying to the north of Montreal. *Ann. Rep. Geol. Surv. Canada*, for 1895, vol. viii., J., p. 83 (1896).

line scales about a millimetre in diameter. This rock is a scapolite pyroxene zoisite rock. The scapolite is abundant and is mostly fresh and clear. The pyroxene is pale-green, almost colourless in thin section; it has the normal prismatic cleavage, and in addition to this, some crystals show a pronounced lamellar structure which apparently follows the basal plane. The augites are very irregular in shape, and, as is usual in these rocks, very rarely show any twinning. It contains many enclosures of other minerals. Hornblende of a rather pale-green colour occurs in this rock, sometimes surrounding augite; there is also a little biotite or phlogopite, dark-reddish brown changing to pale-yellow when the polarizer is rotated. Apatite, small grains of greyish-brown sphene, pyrites, chalcopyrite and iron-oxides are present in small quantities. Between the other minerals there are areas consisting of zoisite, quartz and oligoclase; quartz is fairly common; the oligoclase is perfectly transparent and occasionally shows polysynthetic twinning. Zoisite takes the form of small rod-shaped prisms which very frequently are grouped in bundles or divergent clusters. Sometimes the large zoisites are penetrated by vermiform quartz. The polarization colours given by this mineral are grey and dark-blue.

Another specimen from the same locality illustrates in an interesting fashion the great diversity of this group of rocks. It contains weathered scapolite; no augite; much colourless tremolite in small anhedral prisms; zoisite in large irregular crystals, and in smaller, nearly isodiametral grains, a little pale phlogopite, sphene and iron-oxides. No calcite, quartz or felspars were observed in this rock. The rock is a pale-green scapolite tremolite schist. In the hand specimen it shows pronounced foliation.

*Scapolite-bearing rocks of the Schichallion Boulder-bed.*

A very interesting boulder bed has been mapped in many parts of Perthshire and Argyllshire, mostly on the edge of the white Perthshire quartzite (Schichallion quartzite), between that rock and the Blair Atholl limestone. Some account of this bed is given in the Geological Survey Memoir on Blair Atholl, Pitlochry and Aberfeldy, and many references to it will be found in the SUMMARY OF PROGRESS for recent years. It is mostly a conglomeratic schist or conglomeratic gneiss, very like the Obermittweida gneiss. Its pebbles are mainly gneiss, granite and quartz syenite, or nordmarkite, but Mr. J. S. Grant Wilson obtained two pebbles of scapolite gneiss from this bed; one came from the north side of Schichallion, the other from the Erichdie Water, almost six miles further to the north.

The former of these is a scapolite hornblende gneiss, consisting essentially of quartz, scapolite and green hornblende. In some folia scapolite greatly preponderates; in others quartz; neither of the minerals shows crystalline form. The hornblende is in small grains and larger irregular patches which are filled with rounded crystals of scapolite, quartz, &c. It i[redacted]

rather dark-green and strongly pleochroic. There are many small granules of sphene; chlorite apparently after biotite; a few patches of calcite, and turbid areas which seem to be granular zoisite. No felspar was detected in the slide.

The pebble from the boulder bed on the Erichdie Water is also a well-foliated scapolite gneiss, consisting mainly of scapolite and quartz, with some brown biotite, but no hornblende. It is full of alkali felspar, principally microcline and orthoclase. A curious feature of this rock is the presence of vermicular intergrowths of quartz and scapolite. The scapolite often forms large crystals (two or three millimetres in diameter) always anhedral and filled with enclosures of quartz, felspar, biotite, &c. The usual accessories, viz., sphene, apatite, iron ores and zircon, are present.

The first of these two rocks is an altered sediment and corresponds fairly closely in composition with some of the more impure bands of the Aberdeenshire calc-silicate hornfelses.

The second is rather more doubtful in character, and except for the scapolite might well be a biotite orthogneiss, but the abundance of scapolite renders this improbable. It may be an altered sediment or a mixture of such a rock with intrusive igneous materials.

### II.—SCAPOLITE-BEARING ROCKS OF IGNEOUS ORIGIN—SCAPOLITE ORTHOGNEISSES.

Only three examples of rocks of this kind are included in the collections of the Geological Survey. One comes from the Lewisian gneiss of Badcall, near Scourie, Sutherlandshire. It occurs along with biotite and hornblende gneisses, sometimes containing much epidote, or green pyroxene or garnet. They are typical facies of the Lewisian orthogneisses. The others are spotted scapolite hornblende rocks, which have been mapped as intrusive epidiorites at Crossmount on the north side of Schichallion, and near Trinafour on the Erichdie Water, Perthshire.

The rock from Badcall, Sutherlandshire, is a hornblendite or pyroxenite containing scapolite. In many ways it is unique among British scapolite-bearing rocks. Its principal constituents are dark-green or brownish-green hornblende, pale-green augite, and scapolite; hypersthene also occurs in fair amount though less abundant than the other ferromagnesian minerals. The dark-green hornblende is filled with small granular or rod-shaped black enclosures, often crowded together towards the centres of the crystals but less numerous near the margins. Many of them have an orientation parallel to the orthopinakoid, and bisect the acute angle of the cleavage as seen in cross sections; but other sets running in different directions may be seen in some of the sections. The pale-green augite, like the hornblende, occasionally shows schiller inclusions, especially in the central parts of the crystals. The fine elongated rods appear to lie in the orthopinakoid with their long axes parallel to the ortho-axis of the crystal. The scapo-

lite has a grey striated appearance in ordinary light. Its substance is filled with small black opaque rods, whose long axes are parallel to the vertical axis of the scapolite.* In the hypersthene schiller enclosures also appear but they are broad and flat, rectangular in outline as seen *en face*, but thin and platy when looked at sideways. They lie on the orthopinakoid with their short diameter parallel to *c*; their long diameter to *b*. The hypersthene has strong pleochroism from reddish-pink to clear green. Although traces of idiomorphic outlines may occasionally be seen in the pyroxenes, they are always imperfect, and, as a whole, the grains are quite anhedral. Apatite, iron-oxides, pyrites, and a little brown biotite also appear in this rock and there is a little basic lime-soda felspar (labradorite). All the minerals are in excellent preservation; only the hypersthene shows incipient decomposition. In the hand specimen there is slight foliation. All the characteristics of the minerals of this rock point to its being one of the Lewisian hornblendites or pyroxenites containing a fair proportion of scapolite and very little felspar.

A second scapolite-bearing rock of igneous origin† occurs on the north side of Shichallion, near the Lodge Gate of Crossmount, beside the road from Aberfeldy to Kinloch Rannoch. It forms small rounded rocky knolls in a grassy park and was mapped by Mr. J. S. Grant Wilson as an epidiorite. Its peculiar character in the hand specimen attracted attention at the time, as it is very dark coloured, hardly schistose, and contains many small, grey, rounded spots in a dark-green or black matrix. These spots are about the size of rice grains and are in some specimens arranged in bands, though often they are scattered indiscriminately through the mass. Under the microscope this rock is very fresh, and consists of scapolite and hornblende with some biotite, sphene, apatite, quartz and epidote.

The hornblende is all in short prisms, elongated parallel to the *c* axis, with a pleochroism ranging from dark-green to yellow. Very occasionally signs of the prism faces and clinopinakoids may be detected. There are also a few larger crystals, but they are not prominent. The hornblende forms a network surrounding the clear white spots; these consist of scapolite in single individuals or in groups of crystals. It is rare to find more than traces of crystalline outlines. The scapolite is perfectly fresh, though here and there stained brown by limonite along its cleavage cracks. The larger individuals contain rounded spots of quartz and occasionally small grains of hornblende or of sphene. Iron oxides are comparatively scarce in this rock; there is much granular sphene. Quartz appears as enclosures in hornblende and scapolite. Dark-brown biotite and epidote (with zoisite) are not always present but may be found in some specimens. The

* Lacroix, A.—Contributions à l'Etude des gneiss à pyroxene. *Bull. Soc. Min. France*, vol. xii., p. 99 (1889).

† Memoirs of the Geological Survey. The Geology of the Country around Blair Atholl, Pitlochry, and Aberfeldy, p. 85 (1905).

former mingles with the hornblende; the latter accompanies the scapolite in the round white spots.

An analysis of this rock has been made by Dr. W. Pollard and is given below:—

9519. "100 yards S.E. of Crossmount, 2½ miles E. of Kinloch Rannoch, Perth."

| | |
|---|---|
| $SiO_2$ ... ... ... ... ... ... | 49.11 |
| $TiO_2$ ... ... ... ... ... ... | 1.88 |
| $Al_2O_3$ ... ... ... ... ... | 13.19 |
| $Fe_2O_3$ ... ... ... ... ... | 3.18 |
| $Cr_2O_3$ ... ... ... ... ... | .02 |
| FeO ... ... ... ... ... ... | 8.55 |
| MnO ... ... ... ... ... ... | .42 |
| CaO ... ... ... ... ... ... | 11.27 |
| MgO ... ... ... ... ... ... | 6.76 |
| $K_2O$ ... ... ... ... ... ... | 1.72 |
| $Na_2O$ ... ... ... ... ... ... | 1.91 |
| $H_2O$ 105° C. ... ... ... ... | .11 |
| $H_2O$ above 105° C. ... ... ... ... | .39 |
| (CoNi)O ... ... ... ... ... | .07 |
| $V_2O_3$ ... ... ... ... ... ... | .05 |
| $P_2O_5$ ... ... ... ... ... ... | .18 |
| $FeS_2$ ... ... ... ... ... ... | .36 |
| Cl ... ... ... ... ... ... | .78 |
| | 99.95 |
| Less O for Cl ... ... ... ... | .18 |
| Total ... ... ... ... | 99.77 |

Not found: F, $ZrO_2$, $CO_2$, $Li_2O$, $SO_3$, BaO.
A doubtful trace of $Fe_7S_8$.

Except for the amount of chlorine present this analysis is that of a dolerite or diabase and justifies the inference of Mr. J. S. Grant Wilson from his observations in the field, that this is a basic intrusive rock. There has certainly been an introduction of chlorine, though not in very great amount. No evidence has been obtained to lead us to suppose that any kind of pneumatolytic action has gone on like that which affected the scapolite amphibolites, or spotted gabbros of Oedegarden. Apatite is present, but only in normal amount, as may be seen from the analysis. It is possible that the chlorine, or some of it, may have been derived from the adjacent limestone, though there is nothing to prove that such was the derivation of it.

A rock in almost all respects almost identical with the last mentioned was collected by Mr. Macconochie one and a quarter miles north-north-east of Trinafour Lodge. It is not quite so fresh and contains a little alkali felspar mixed with the scapolite, but is so similar as to need no special description. It seems to be part of a large sill of epidiorite in the quartzite, and if not the same as that of Crossmount, must, at any rate, be very nearly on the same horizon.

No other one of the numerous epidiorite sills around Trinafour is known to contain scapolite. A microscopic section of

one of these sills from a quarter of a mile west of Trinafour Lodge bears a very close resemblance in many respects to the scapolite amphibolites of this locality. The hand specimens, however, have not the spotted character which distinguishes the latter rocks, and in the slides there is no scapolite. The hornblende, biotite and sphene are very similar in appearance, relative amount, and distribution in the two rocks, but the scapolite is represented by a mosaic of rounded grains of often untwinned labradorite (Ab 55 An 45). As Professor Judd has shown, the addition of a small proportion of sodium and chlorine is all that is required to change such a felspar into scapolite.*

## SUMMARY AND CONCLUSIONS.

The scapolite-bearing rocks of Scotland are not numerous, yet taken collectively they contain a considerable variety of minerals and present a great diversity of types.

The majority of them are metamorphic limestones and calc-silicate rocks of sedimentary origin; a few are metamorphic intrusive rocks; there are others of which the nature is not perfectly clear.

They occur in the Lewisian gneiss, in the limestone series of the Central Highlands (Blair Atholl limestone), and as pebbles in the Schichallion boulder-bed. They are not known either in the Moine rocks or in association with the Loch Tay limestone.

The scapolite-bearing rocks of sedimentary origin mostly are found in the vicinity of intrusive igneous masses and under such circumstances as make it probable that they have suffered contact alteration. The only exception to this is the pebbles which are found in the Schichallion boulder-bed.

### I.—SCAPOLITE-BEARING ROCKS OF SEDIMENTARY ORIGIN.

These may be divided into the following groups:—

*A. Scapolite Mica Schists.*—Two examples of these have been found in Scotland; one in the Forest of Glen Ey, Aberdeenshire (in the Blair Atholl limestone group): the other in the Lewisian at Loch Gairloch, Ross-shire (Fig. 2 of Plate). In both of these the matrix is a fine mica schist or schistose biotite hornfels. The scapolites are large pseudo-porphyritic or porphyroblastic; one of these rocks contains pyroxene, the other amphibole; both are garnetiferous. The Glen Ey scapolite biotite hornfels is in contact with the acid sills which accompany the newer granites of Aberdeenshire, the other accompanies the orthogneisses of the Lewisian. The nearest analogue to these rocks is provided by the Lias of the Pyrenees, where it is altered by intrusive lherzolite and ophite.†

*B. Scapolite Biotite Gneisses.*—These are represented by one pebble from the Schichallion boulder-bed on the Erichdie Water, Perthshire. It is a well-foliated, highly metamorphic

* *Min. Mag.* viii., p. 188. See also *Metamorphism.*—Van Hise, p. 264.

† Lacroix. A.—Les phénomenes de contact de la Lherzolite et de quelqres ophites des Pyrenées. *Bulletin des Services de la Carte Géologique de la France*, No. 42 1895.

rock with much quartz, microcline, orthoclase and scapolite. The latter mineral is in large crystals penetrated by vermicular quartz. In all probability this is a sedimentary gneiss, though from its occurrence as a foreign pebble in a conglomerate, its original relations cannot be investigated. Similar rocks have, however, been described by several writers as modifications of granitic or gneissic intrusives by admixture with calcareous sedimentary material.* At any rate, this cannot be held to be a normal orthogneiss.

*C. Scapolite bearing metamorphic Limestones and Cipolins.*—This group has more representatives than any of the others. Examples occur at Creag Breag, Criag an Ordaich, and Gillan (Aberdeenshire); Glen Effock (Forfarshire); Glen Meran (Perthshire); Tiree; Armadale (Sutherlandshire); and Gortally (Inverness-shire). The commonest minerals in these rocks, in addition to calcite and scapolite, are colourless and pale-green pyroxene (malacolite and diopside or coccolite), sphene, epidote and zoisite, garnet (usually doubly refracting), vesuvianite, colourless or green hornblende, biotite or phlogopite, apatite, various felspars, quartz, iron oxides and pyrites. Wollastonite is found in some of the associated calc-silicate hornfelses. Intrusive orthogneiss, granite or diorite are in all cases found in proximity to the rocks of this group.

The minerals are rarely eumorphic. Augite, garnet and hornblende occasionally show traces of crystalline form. Calcite and scapolite more commonly serve as a sort of matrix. Sphene, zoisite and iron oxides when in small crystals may be fairly well shaped. The larger individuals of garnet, augite and scapolite may be filled with enclosures of the others.

*D. Scapolite Pyroxene rocks and Scapolite Hornblende rocks.*—Many of these are banded, others are nearly massive and resemble calc-silicate hornfelses, with which they have very close affinities. Calcite sometimes occurs in them in small quantity. The minerals found in this group are:—scapolite, colourless and green augite, tremolite and pale-green hornblende, zoisite, epidote, garnet and sphene, vesuvianite, apatite, graphite, iron oxide, pyrite, and chalcopyrite, biotite or phlogopite, muscovite, quartz, alkali felspars, oligoclase. They have generally the properties of those which occur in the previous group of rocks.

Scapolite pyroxene rocks occur in Glen Meran (Perthshire); scapolite tremolite zoisite rocks in Allt Garbh Coire (Inverness-shire); scapolite pyroxene zoisite rocks at the last-named locality and at Armadale (Sutherlandshire). The only English scapolite-bearing rock with which I am acquainted belongs to this group. It comes from Walkhampton, near Princetown on the borders of Dartmoor and has been described by Dr. Teall.†

* Lacroix, A.—Contributions à l'Etude des gneiss à pyroxene. *Bull. Soc. Min. France*, vol. xii., p. 119 (1889).

† Annual Report of Geological Survey of the United Kingdom, 1896, p. 50 (1897).

As scapolite amphibolites and scapolite pyroxenites of igneous origin occur in the Scottish Highlands and have somewhat the same association of minerals as the rocks of this group, ambiguity may often arise as to the nature of individual specimens. This can only be decided by an investigation of the structure and peculiarities of the minerals of each rock, accompanied by a determination of their field relationships. In all the cases above cited, the rocks in question form part of a limestone series into which they pass by gradual transitions, and the evidence seems sufficient to prove that they also are sediments. It must often be impossible to arrive at a conclusion from the microscopic examination of individual specimens. The association of scapolite-pyroxene gneiss with limestones has frequently been observed.*

*E. Scapolite Epidote rocks.*—The only example of these is the rock from Cnoc na h' Ula, Laxford, Sutherlandshire. It is not possible to make certain whether this rock is igneous or not.

*F. Scapolite Gneisses.*—This name is reserved for those rocks which contain scapolite with a considerable amount of quartz and felspar (cf. I. b. scapolite-biotite gneiss). They may be divided into scapolite-pyroxene gneisses and scapolite-hornblende gneisses, but many examples contain both augite and hornblende. Epidote and zoisite are common in these rocks. From their associations and the characters of their minerals they are placed among the sedimentary gneisses or paragneisses, and certainly in most cases they belong to this group, but it is possible that some intrusive gneisses which have absorbed calcareous materials may be included. Rocks of this kind are found at Allt Coire Dubh (Inverness-shire) and Glen Meran (Perthshire) as above noted. Some of the scapolite-pyroxene rocks and scapolite-hornblende rocks of Group I, D may contain small amounts of quartz and felspar. The scapolite-hornblende gneiss which occurs in the boulder-bed of Schichallion is exceptionally poor in felspar.

## II.—METAMORPHIC IGNEOUS ROCKS CONTAINING SCAPOLITE.

Rocks of this kind are much rarer than those of Class I. Only three occurrences are known in the Scottish Highlands and these provide only two kinds of rock.

*A. Scapolite Pyroxenite.*—This is found at Badcall near Scourie. It contains scapolite, pyroxene, hornblende, hypersthene and basic felspar. The structure of the rock and the characters of its minerals are those of the pyroxenites of the Lewisian. It is the only British scapolite-bearing rock containing hypersthene. The felspar is fresh and clear, and it is quite an open question whether the scapolite is not an original mineral.

*B. Scapolite Amphibolite.*—This rock is known to occur at

* Becke, F.—Die Gneissformation des Niederösterreichischen Waldviertels, *Tschermaks Min. Pet Mittheil*, Iv., p. 367 (1882).

Crossmount, and near Trinafour, in Perthshire. It is a modification of the epidiorite sills of the region, containing scapolite instead of the usual felspar (labradorite). The only other mineral of importance is dark-green hornblende. The rock shows a pronounced spotting. There is no evidence to prove that it has been modified by pneumatolytic processes like the 'spotted gabbros' (scapolite hornblende rocks) of Oedegarden. We are rather led to believe that, like some of the Pyrenean ophites described by Prof. Lacroix,* it has experienced some kind of alteration by percolating solutions; and the mineral change may partly have taken place before the dynamic metamorphism which has affected all the rocks of this region.

## Explanation of Plate.

### Photomicrographs of scapolite-bearing rocks.

Figure 1.—*Marble* (with pyroxene and scapolite).
Creag Bheag, 2½ miles west of Balmoral, Aberdeenshire.
(Slide No. 9,670; magnified 25 diameters.)
The rock is rather fine-grained and consists of small rounded or irregular crystals of calcite, recognizable by their cleavage, twinning and roughish surfaces. The clear mineral which in small grains fills up the spaces between the calcites, is mostly scapolite, but partly also untwinned or simply twinned alkali felspar. It is most conspicuous near the bottom of the photograph. The granules with very high refractive index and dark borders are green pyroxene.

Figure 2.—*Scapolite zoisite pyroxene rock.*
Burn, east of Creag Garbh, 1 mile north-north-west of Armadale, Sutherlandshire.
(Slide No. 5,164; magnified 25 diameters.)
This consists principally of clear green or nearly colourless augite, of which several crystals are visible in the photographic field, exhibiting their perpendicular cleavages. The scapolite is colourless and slightly turbid through decomposition; one mass occupies the centre of the view, enclosing a branching aggregate of pyrites which photographs as a black object. The mineral with granular, rough surface at the upper left corner is zoisite. Many small lozenge-shaped crystals of sphene are also visible in the slide.

Figure 3.—*Scapolite pyroxene rock.*
Head of Glen Meran, Glen Lyon, Perthshire.
(Slide No. 4,243B; magnified 25 diameters.)
The photograph shows large crystals of green augite, bounded by the vertical pinakoidal faces, surrounded by a turbid mass of slightly decomposed scapolite.

Figure 4.—*Scapolite mica schist.*
Half a mile east of Fraoich Eilean, Loch Gairloch, Ross-shire.
(Slide No. 4,342; magnified 31 diameters.)
Rounded porphyroblastic crystals of fresh scapolite lie in a schistose matrix of biotite, quartz and iron oxides, with possibly a little felspar. Small garnets occur also in this rock, but are not visible in the photograph. The scapolites do not contain enclosures of the matrix.

Figure 5.—*Scapolite pyroxenite.*
Badcall, near Scourie, Sutherlandshire.
In the centre is a large crystal of scapolite; its dusty appearance is due to minute dark enclosures, like those of schillerized felspar. The clear patch above and to the right is basic felspar. The

* Lacroix, A.—Minéralogie de la France et de ses Colonies, vol. ii., p. 229.

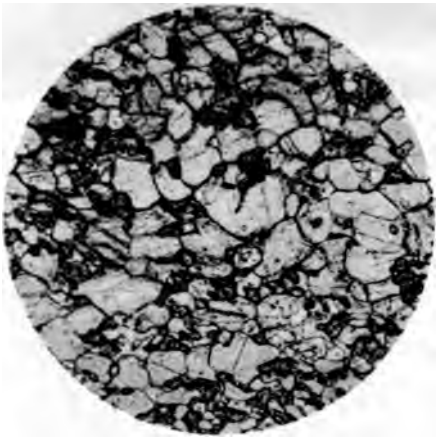

Fig. 1.

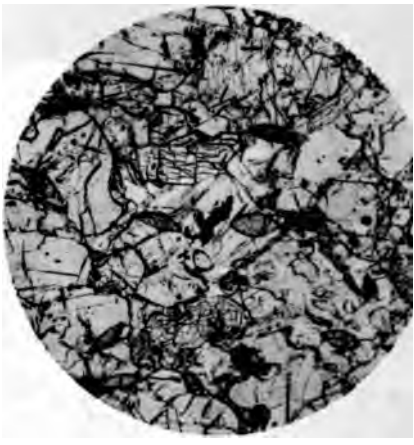

Fig. 2.

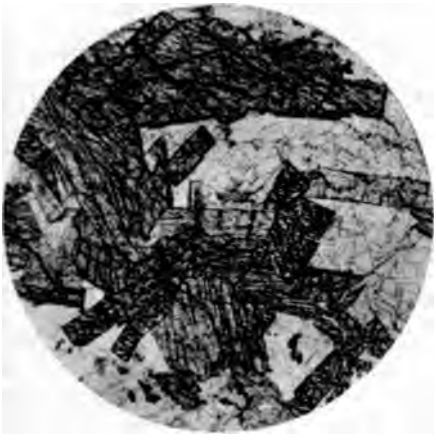

Fig. 3.

Fig. 4.

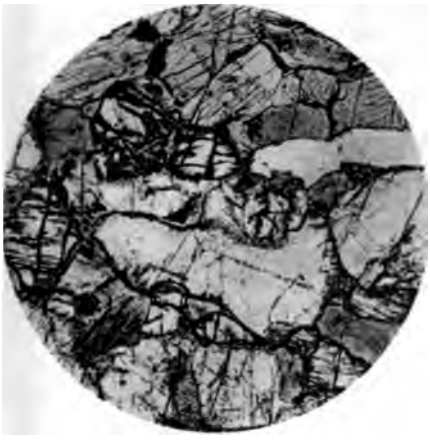

Fig. 5.

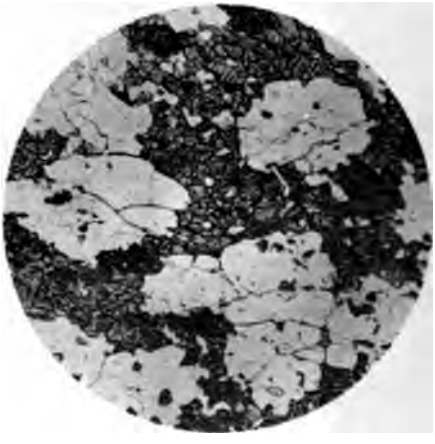

Fig. 6.

hypersthene is recognizable by its showing incipient decomposition along its cleavages; its colours are pale-pink and pale-green. The remainder of the rock consists mainly of green augite and brownish-green hornblende in nearly equal proportions. Hornblende forms most of the upper part of the field and shows its characteristic cleavage in one crystal; rounded grains of augite appear below and to the right. Both these minerals show lines of dark enclosures. Iron oxides and pyrites are also present in the slide.

Figure 6.—*Scapolite amphibolite.*

Crossmount Lodge, north side of Schichallion, Perthshire.
(Slide No. 11,290; magnified 25 diameters.)

The spotted or flecked character of these rocks is well shown in the photograph. The clear areas are crystals or crystal aggregates of fresh scapolite. They are enveloped in a network of granular green amphibole, mixed with sphene (which photographs in darker shades) and iron oxides

## II.—Total Quantity of Tin, Copper, and other Minerals produced in Cornwall, particularly with regard to the Quantities raised from each Parish.

By Donald A. MacAlister, A.R.S.M.

Statistical returns, giving the total annual output of tin and copper from the mines of Cornwall and Devonshire, are fairly complete from about the middle of the eighteenth century, with the exception of a few breaks in the record the items of which can be estimated.*

The statistics relating to copper are known year by year as far back as 1726, and for tin to 1750, but from 1818 to 1881 the figures relating to tin include the output of both Cornwall and Devon. Since by far the greater quantity of tin ore has been raised in Cornwall, the inclusion of the amount produced by Devon during the period mentioned does not seriously affect the grand total.

For centuries no statistics were kept but some thousands of tons of tin and hundreds of tons of copper were produced annually of which no attempt has here been made to estimate the probable total output owing to the lack of data.

From the information above referred to the total amount of metallic tin produced in Cornwall between 1750 and 1905 amounts at least to 755,900 tons,† which was obtained from dressed 'black tin' containing 65.02% of available metal.‡

The total amount of metallic copper raised during the same period is 719,250 tons, but between 1726 and 1905 there has been at least 883,350 tons of metallic copper produced from ore containing an average of 7.89% of available copper.§

The preparation of the following statistical tables, giving the output of minerals from the parishes of Cornwall, has been beset with difficulties which have been satisfactorily overcome, but in order that their accuracy may be gauged the various

* See "Geology of Falmouth and Truro, and of the Mining District of Camborne and Redruth," by J. B. Hill, R.N., and D. A. MacAlister (1906), pp. 306-308.

† Includes the amount produced in Devon between 1818 and 1881.

‡ Mr J. H. Collins in his "Seven Centuries of Tin Mining in Cornwall," (*Trans. Mining Assoc. and Inst. of Cornwall*, 1892), estimates the total produce of metallic tin in the West Country between 1201 and 1800 A.D. to be 857,900 tons, from which it may be reckoned that 711,990 tons were yielded between 1201 and 1750 A.D. from both Cornwall and Devon. Of 283,000 tons of tin yielded between 1201 and 1600 A.D., 75,000 were derived from tin-stream gravels; and of 573,800 tons yielded between 1601 and 1800 A.D., 473,000 tons were derived from tin-stream gravels.

§ Mr. J. H. Collins in his "Four Centuries of Copper Production in the West of England" (*Trans. Mining Assoc. and Inst. of Cornwall*, 1895, Falmouth), estimates the total yield of copper ore from the West of England between 1501 and 1890 A.D., to be 11,442,170 tons, of which it may be reckoned that 243,000 tons were produced between 1501 and 1725 A.D.

sources of error are mentioned below, while the total output of tin and copper for the period dealt with has been obtained from two sources, so that the extent of error to which the figures representing the parish totals are liable is indicated.

The periods for which the parish totals can be compiled are limited by the periods for which the output of minerals from individual mines are obtainable, since it is by the grouping of these mines, according to the parishes in which they occur, that the output of minerals from each parish was obtained.

For tin, the details of the output of individual mines are obtainable from 1852 to the present, and for copper from 1815,* so that the parish totals for these minerals are restricted to the same period.

The total amount of tin produced between 1852 and 1905, as computed from these details, is 364,950 tons, obtained from 561,290 tons of dressed tin ore (or 'black tin'), while the amount estimated from the annual returns for the whole of Cornwall from all sources for the same period (including 'stream-tin,' &c.), is 409,260 tons, which was obtained from 629,770 tons of 'black tin.'

There is, therefore, a discrepancy of 44,310 tons (or a little under 10% of the larger total) which is partly accounted for by the incompleteness and inaccuracy of the records relating to the output of individual mines, and by the fact that the alluvial or 'stream-tin' deposits of the rivers and upland moors are not included in the parish totals.

The amount of copper produced from the mines of Cornwall between 1815 and 1905, as computed from parish totals, is 568,480 tons, which was obtained from 7,161,550 tons of copper ore.

The total for the same period, as determined from published returns for the whole of Cornwall, is 630,400 tons of copper obtained from ore containing 7.89% of available metal. There is between these two totals a discrepancy of 61,920 tons (or a little over 10% of the larger amount) which can only be accounted for by the incompleteness of the records relating to the output of minerals from individual mines.

Finally, in using the table as a general guide to the mineral productiveness of the different parishes, it should be recollected that in addition to the fundamental inaccuracies, amounting in the aggregate to a deficiency of 10%, the table itself does not go further back than 1852 for tin ore and 1815 for copper. In many cases where mines are situated on parish boundaries the figures representing the output have been lumped together under one parish or the other without any attempt being made to divide the yield between them.

* See Memoir previously cited, pp. 274-289.

*Output of Tin and Copper from the Mines of Cornwall grouped according to the Parishes in which they occur. The Tin Ore produced from 1852 to 1905, and the Copper Ore from 1815 to 1905.*

| Parish. | Black Tin. | Copper Ore. | Copper. | Parish. | Black Tin. | Copper Ore. | Copper. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | | Tons. | Tons. | Tons. |
| Altarnun ... | 200 | 50 | 5 | St. Agnes ... | 29,790 | 189,500 | 12,680 |
| Bodmin ... | 150 | 700 | 45 | St. Austell ... | 23,700 | 80,000 | 5,200 |
| Breage ... | 26,010 | 112,000 | 8,910 | St. Blazey ... | 5,770 | 300,200 | 26,750 |
| Callington ... | 450 | 2,900 | 140 | St. Breward ... | — | 1,000 | 40 |
| Calstock ... | 7,520 | 147,400 | 8,925 | St. Cleer ... | 430 | 248,500 | 24,080 |
| Camborne ... | 106,100 | 780,000 | 56,600 | St. Columb Major... | 75 | — | — |
| Constantine... | 100 | 8,500 | 510 | St. Dennis ... | 100 | — | — |
| Crowan ... | 1,500 | 213,000 | 14,840 | St. Enoder ... | 900 | — | — |
| Germoe ... | 2,050 | — | — | St. Erth ... | 2,280 | 76,900 | 4,680 |
| Gwennap ... | 7,810 | 1,593,000 | 134,700 | St. Ewe ... | 210 | 120 | 10 |
| Gwinear ... | 2,840 | 88,800 | 7,970 | St. Hilary ... | 3,410 | 102,700 | 7,110 |
| Illogan ... | 152,600 | 1,044,400 | 79,470 | St. Ive ... | — | 37,600 | 2,590 |
| Kea ... ... | 4,400 | 15,800 | 1,040 | St. Ives ... | 13,120 | 33,000 | 2,540 |
| Kenwyn ... | 8,200 | 152,600 | 8,460 | St. Just ... | 69,260 | 147,000 | 13,990 |
| Ladock ... | 30 | — | — | St. Mewan ... | 4,000 | 1,100 | 85 |
| Lanivet ... | 1,940 | 27,000 | 1,370 | St. Neot ... | 200 | 13,200 | 800 |
| Lanlivery ... | 5 | 150 | 10 | St. Stephen in Brannel... | 1,410 | 75 | 5 |
| Launceston ... | some | — | — | St. Winnow... | — | 4,000 | 165 |
| Linkinhorne | 17,100 | 363,000 | 25,050 | Sancreed ... | 20 | — | — |
| Ludgvan ... | 3,770 | 42,300 | 3,345 | Sithney ... | 170 | 8,500 | 565 |
| Luxulian ... | 55 | 2,100 | 240 | South Hill ... | 120 | 50 | 8 |
| Madron ... | 2,910 | — | — | Stoke-Climsland... | 1,000 | 76,500 | 4,440 |
| Marazion ... | 400 | 41,000 | 2,910 | Tewington ... | 170 | — | — |
| Morvah ... | 105 | — | — | Towednack... | 1,420 | 500 | 50 |
| Newlyn ... | — | 540 | 80 | Tywardreath | 30 | 383,000 | 30,160 |
| North Hill ... | — | 400 | 30 | Uny Lelant | 13,380 | 14,400 | 1,070 |
| Paul ... ... | — | 40 | 2 | Wadebridge ... | — | 20 | 5 |
| Penzance ... | (?)1,000 | — | — | Warleggon ... | 610 | 2,100 | 140 |
| Perran-uthnoe... | 130 | 35,360 | 3,050 | Wendron ... | 17,300 | 800 | 50 |
| Perran-zabuloe... | 1,940 | 181,700 | 11,490 | Withiel ... | 20 | — | — |
| Phillack ... | 25 | 101,000 | 6,810 | Zennor ... | 160 | 50 | 5 |
| Redruth ... | 22,700 | 625,000 | 54,850 | | | | |
| Roche ... | 250 | — | — | | | | |

The statistics relating to minerals other than those of tin and copper are compiled from details extending over a limited period dating from 1845. Previously to this no returns of output appear ever to have been published in a regular way. In all probability the errors in the earlier published details are considerable, so that the general restrictions referring to the use of the tables of the tin and copper output apply to the miscellaneous minerals in the following table. Where the amount of ore as well as the amount of metal obtained from it is given, it always refers to the dressed materials from the mines.

*Output of Minerals, other than Tin and Copper, from the Mines of Cornwall grouped according to the Parishes in which they occur. The Lead Ore raised since* 1845; *the Silver since* 1852; *and the Miscellaneous Minerals since* 1853.

| Parish. | Lead ore. | Lead. | Silver. | Zinc ore. | Iron pyrites and sulphur ores. | Crude and refined arsenic. | Other products. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Ozs. | Tons. | Tons. | Tons. | |
| Altarnun ... | ... | ... | ... | ... | ... | ... | 500 tons of manganese ore. |
| Bodmin ... | 10 | 7 | 80 | ... | ... | ... | |
| Boscarne ... | ... | ... | ... | ... | ... | ... | 2,200 tons of brown hæmatite. |
| Breage ... | ... | ... | ... | ... | ... | 330 | 4 tons of silver ore. |
| Callington | 6,640 | 4,230 | 10,200 | 25 | 1,100 | 3,420 | Silver obtained from lead but the amount is understated. The copper also yielded some silver. |
| Calstock ... | 215 | 140 | 1,810 | 10 | 22,000 | 6,575 | 30,000 tons of mispickel (arsenical iron pyrites). 270 tons of silver ore. Before 1833 over £10,000 worth of silver ore sold. 3 tons of copper and silver precipitate. 405 tons of wolfram. 25 tons of ochre and umber. |
| Camborne ... | 110 | 75 | ... | 645 | 275 | 9,400 | 340 tons of silver ore. 2 cwts. of bismuth ore. |
| Camelford ... | 180 | 108 | ... | ... | ... | ... | |
| Cardinham | 20 | 15 | ... | ... | ... | ... | |
| Crowan ... | 10 | 7 | 15 | 3 | 750 | some | 100 tons of brown hæmatite. |
| Cubert ... | 1,150 | 720 | 6,550 | ... | ... | ... | 2,500 tons of hæmatite. |
| Egloshayle | 55 | 33 | ... | ... | ... | ... | |
| Endellion ... | ... | ... | ... | ... | ... | ... | 15 tons of antimony ore (some containing 43 per cent. antimony). |
| Falmouth ... | 900 | 180 | 3,580 | ... | ... | ... | ... |

| Parish. | Lead ore. | Lead. | Silver. | Zinc ore. | Iron pyrites and sulphur ores. | Crude and refined arsenic. | Other products. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Ozs. | Tons. | Tons. | Tons. | |
| Gwennap ... | 25 | 18 | ... | 1,360 | 8,270 | 1,300 | 38 tons of oxide of iron. 321 tons of ochre and umber. 2,000 tons of mispickel (arsenical pyrites). 1,080 tons of fluorspar. 20 tons of wolfram, and 4 tons of silver ore. |
| Gwinear ... | some | some | ... | 400 | 15 | 260 | 2,610 ozs. of silver from silver ore, and also £9,000 worth of silver. |
| Gwithian ... | 75 | 55 | ... | 25 | ... | ... | |
| Illogan ... | 800 | 535 | 13,900 | 270 | 1,350 | 36,000 | 1,230 tons of mispickel (arsenical pyrites). 1,220 tons of wolfram. |
| Kea ... | 3,870 | 2,750 | 58,150 | 2,000 | 111500 | 800 | 14,400 tons of oxide of iron (gossan). 222 tons of ochre. 05 tons of mispickel. |
| Kenwyn ... | 2,150 | 1,170 | 74,200 | 1,390 | 1,180 | 2,285 | 20,840 tons of mispickel. 380 tons of oxide of iron. 311 tons of ochre. |
| Ladock ... | ... | ... | ... | ... | ... | ... | 8,840 tons of hæmatite. |
| Lanivet ... | ... | ... | ... | 156 | 30 | ... | 32,820 tons iron ore. |
| Lanlivery ... | ... | ... | ... | ... | ... | ... | 90,810 tons iron ore. |
| Lanreath ... | 19,530 | 14,270 | 617,270 | ... | ... | ... | 5 tons wolfram. |
| Launceston | ... | ... | ... | ... | ... | 246 | 21 tons manganese ore. 14 tons tungstate of soda. 20 tons arsenical pyrites. 540 tons of brown hæmatite, of which 400 tons contained 15 percent. manganese. |
| Lelant ... | ... | ... | ... | 10 | ... | 20 | |

| Parish. | Lead ore. | Lead. | Silver. | Zinc ore. | Iron pyrites and sulphur ores. | Crude and refined arsenic. | Other products. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Ozs. | Tons. | Tons. | Tons. | |
| Lezant ... | some | some | ... | ... | ... | ... | 95 tons manganese ore. 20 tons ochre. |
| Liskinhorne | 90 | 65 | 200 | 105 | 640 | ... | |
| Liskeard .. | some | some | ... | ... | ... | ... | |
| Luxulian ... | ... | ... | ... | ... | ... | ... | 10,500 tons iron ore. |
| Marazion ... | some | some | ... | 10 | ... | ... | 14 tons of silver ore yielding 3,440 ozs. of silver. |
| Mawgan ... | ... | ... | ... | ... | ... | ... | 940 tons brown hæmatite. |
| Menheniot... | 53,690 | 44,210 | 2,010,000 | ... | 920 | 460 | 7,230 tons mispickel. |
| Minster ... | ... | ... | ... | ... | ... | ... | 52 tons of magnetic iron ore (Boscastle). |
| Newlyn ... | 5,720 | 41,705 | 412,825 | 4,070 | 550 | ... | |
| Padstow ... | 75 | 56 | 270 | ... | ... | ... | |
| Perranuthnoe | some | some | 21,000 | ... | 3 | 10 | 1,730 tons brown hæmatite. |
| Perranzabuloe | 55,620 | 40,020 | 1,321,000 | 58,760 | 1,705 | 50 | 108,020 tons hæmatite. 180 tons ochre and umber. 2 tons wolfram. 15,110 tons spathic iron ore. 185 tons argentiferous copper. 7 tons rich silver-lead ore. |
| Phillack ... | 410 | 305 | 5,000 | 110 | 120 | ... | |
| Redruth ... | ... | ... | ... | 25 | 96 | 410 | 50 tons ochre. 291 tons fluorspar. |
| Roche ... | ... | ... | ... | ... | ... | ... | 29,670 tons iron ore. |
| St. Agnes ... | 115 | 80 | 30 | 290 | 840 | 20 | 203 tons arsenical pyrites. |
| St. Austell... | 325 | 200 | 950 | 980 | 2,840 | ... | 81,070 tons iron ore. 64 tons mispickel. 70 tons wolfram. 6 tons of gossan. Some nickel. |
| St. Blazey ... | some | ... | ... | 980 | 5,480 | ... | 4,785 tons iron ore. |
| St. Breward | ... | ... | ... | ... | 4,940 | ... | |
| St. Cleer ... | ... | ... | ... | 240 | ... | ... | |

| Parish. | Lead ore. | Lead. | Silver. | Zinc ore. | Iron pyrites and sulphur ores. | Crude and refined arsenic. | Other products. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Ozs. | Tons. | Tons. | Tons. | |
| St. Columb Major | ... | ... | ... | ... | ... | ... | 3,010 tons iron ore. 1,022 tons manganese ore. 471 tons ochre and umber. |
| St. Enoder... | 15 | 10 | 3,000 | ... | ... | ... | 18,480 tons iron ore and some ochre. |
| St. Erth ... | ... | ... | ... | 1,400 | 12 | ... | |
| St. Ewe ... | ... | ... | ... | ... | ... | ... | Some nickel. |
| St. Hilary ... | 65 | 40 | ... | ... | 200 | 1,210 | |
| St. Issey ... | ... | ... | ... | ... | 40 | ... | |
| St. Ive ... | 10,850 | 7,410 | 298,250 | ... | ... | ... | 12 tons silver ore. 156 tons rich silver-lead. |
| St. Ives ... | ... | ... | ... | 300 | 35 | ... | |
| St. Just ... | 5 | 4 | ... | ... | ... | 2,240 | 75 tons of ochre and iron ore. |
| St. Kew ... | 30 | 21 | ... | ... | ... | ... | 22 tons antimony ore. |
| St. Mellion | ... | ... | ... | ... | ... | ... | 1,390 tons mispickel. |
| St. Mewan... | 20 | 12 | 50 | ... | ... | ... | 1,724 tons iron ore. 40 tons ochre and umber. |
| St. Minver | 990 | 658 | 19,070 | ... | ... | ... | |
| St. Neot ... | 140 | 95 | 1,010 | ... | ... | 40 | |
| St. Stephen in Brannel | 480 | 314 | 2,970 | ... | 1,212 | 2 | 4 tons cobalt ore. 135 tons nickel and cobalt ore. 455 tons uranium ore. 500 tons magnetic iron ore. 2,500 tons manganese ore. 18,550 tons iron ore. |
| St. Teath ... | 2,180 | 1,640 | 9,530 | 45 | 120 | ... | 62 tons brown hæmatite. |
| St. Winnow | 4 | 3 | 40 | 215 | ... | ... | Some silver ore also. |
| Sithney ... | 120 | 12 | ... | 4 | ... | ... | |
| South Hill... | 280 | 150 | 9,170 | ... | ... | 60 | 90 tons arsenical pyrites. 8 tons silver ore. |

| Parish. | Lead ore. | Lead. | Silver. | Zinc ore. | Iron pyrites and sulphur ores. | Crude and refined arsenic. | Other products. |
|---|---|---|---|---|---|---|---|
| | Tons. | Tons. | Ozs. | Tons. | Tons. | Tons. | |
| Stoke-Climsland | 2,000 | 1,310 | 21,150 | 1,125 | 14,010 | 15,060 | 84 tons wolfram. 24,820 tons of arsenical pyrites. 108 tons fluorspar. 53 tons of copper and silver precipitate. |
| Tintagel ... | ... | ... | ... | ... | ... | ... | 40 tons carbonate of iron. |
| Tywardreath | ... | ... | ... | 50 | 2,290 | ... | 8 tons nickel ore. Some ochre. |
| Warleggon | 20 | 12 | 140 | ... | ... | ... | 49,500 tons brown hæmatite. |
| Withiel ... | ... | ... | ... | ... | ... | ... | 35,800 tons iron ore. |

## III.—Some Well-sections in Middlesex. By W. Whitaker, B.A., F.R.S., and G. Barrow, F.G.S.

In vol. ii. (pp. 79-182, 302, 304, 335, 336) of the Memoir "The Geology of London," &c., published in 1889, there appeared notes of 309 well-sections in Middlesex, including such as had been already published, together with many new ones.

In 1897 an account of 51 other wells was communicated to the British Association of Waterworks Engineers and published in the following year in vol. ii. of its Transactions (pp. 76-109, including discussion), thus bringing the total to 360, besides two previously published elsewhere and now reprinted.

Since then a few notices of new wells have appeared (in newspapers or other periodicals) which are now collected together, and the kindness of various well-sinkers and others has enabled the writers to add a goodly number of unpublished descriptions. The whole comes to 54 (of which 46 are new), bringing the total for the county to 413, as one of those printed in the London Memoir (p. 171) should be deducted. It was wrongly entered as in Upper Thames Street, whereas it should have been entered as at Rotherhithe, in Surrey; a correction which is welcome, on account of its getting rid of a great difficulty in reconciling the section with all that is known of the surroundings of the former site. W. W.

[In the following notes words in square brackets have been added by the writers.]

### Ashford (One and a half miles east of Staines). West London District Schools, 1891.

Made and communicated by Messrs. Tilley.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [River] Gravel ... ... ... ... ... ... | | 17½ | 17½ |
| London Clay, basement-bed included ... ... | | 217½ | 235 |
| [Reading Beds, 65 feet] | Mottled clay ... ... ... ... | 26 | 261 |
| | Sand ... ... ... ... ... | 3 | 264 |
| | Mottled clay ... ... ... ... | 19 | 283 |
| | Sand ... ... ... ... ... | 6 | 289 |
| | Mottled clay ... ... ... ... | 11 | 300 |

### Bow. Charing Cross and City Electric Co., Marshgate Lane.

About 10 feet above Ordnance Datum.

Made and communicated by Messrs. Isler & Co.

Lined with 140 feet of tubes, of 13½ inches diameter, from 8 feet above basement, and with 40 feet of 15½ inches diameter, level with basement.

Water-level 39 feet down. Supply 13,000 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [River Gravel] Ballast... ... ... ... ... | | 15½ | 15½ |
| [London Clay, 74 feet] | Blue clay ... ... ... ... | 34 | 49½ |
| | Clay and stones [septaria?] ... | 11 | 60½ |
| | Blue clay ... ... ... ... | 29 | 89½ |
| [Lower London Tertiaries, 36½ feet] | Loamy sand and pebbles ... ... | 15 | 104½ |
| | Black sand ... ... ... ... | 9 | 113½ |
| | Sand and pebbles ... ... ... | 6 | 119½ |
| | Grey sand ... ... ... ... | 2 | 121½ |
| | Green sand ... ... ... ... | 2 | 123½ |
| | Green-coated flints .. ... ... | 2½ | 126 |
| Chalk and flints... ... ... ... ... ... | | 274 | 400 |

This section is hard to make out. The thickness assigned above to the Lower London Tertiaries is very small, rather less than the Thanet Sand alone should have. The greater part of this, moreover (the top 30 feet), reads as if we had Oldhaven Beds in force, and there is nothing that reads like Woolwich and Reading Beds. Can it be that we have here an underground case of that erosion at the base of the Oldhaven or Blackheath Beds (that division cutting through the Woolwich and Reading Beds and nearly to the base of the Thanet Sand), of which there is such such plentiful evidence at the surface southward, in Surrey, where at last the Blackheath Beds cut off all the underlying Tertiary Beds and much of the Upper Chalk? On the other hand, too great a thickness may have been assigned to the London Clay.—W. W.

## Bunhill Row. Bovril Co., 1899.

London Map 7 N.E.

Made and communicated by Messrs. Le Grand and Sutcliff.

62 feet above Ordnance Datum. Water-level 139 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Basement | | — | 9 |
| [River Gravel] | Ballast... | 16 | 25 |
| [London Clay, 52 feet] | Brown clay and stone | 1 | 26 |
| | Blue clay and stone | 51 | 77 |
| [Reading Beds, 43½ feet] | Mottled clay | 12 | 89 |
| | Loamy sand | 2 | 91 |
| | Hard sand | 8 | 99 |
| | Pebbles and clay | 4 | 103 |
| | Pebbles | 5 | 108 |
| | Hard sand | 2 | 110 |
| | Mottled clay and pebbles | 5½ | 115½ |
| | Hard green sand | 5 | 120½ |
| [Thanet Sand] | Thanet sand | 32½ | 153 |
| | Green flints | 2 | 155 |
| Chalk and flints... | | 254 | 409 |

## Cattle Market. Messrs. Slaters.

London Map 7 N.W.

Made and communicated (1906) by Messrs. Isler & Co.

200 feet of tube, of 13½ inches diameter, 7½ feet down. About 150 feet above Ordnance Datum. Water-level 191 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made Ground | | 2½ | 2½ |
| [London Clay, 121½ feet] | Brown clay | 3 | 5½ |
| | Brown and blue clay... | 17 | 22½ |
| | Sandy clay, with claystone from 26½ to 27½ | 12 | 34½ |
| | London clay | 71½ | 106 |
| | Sandy clay | 18 | 124 |
| [Reading Beds, 46 feet] | Mottled clay | 24½ | 148½ |
| | Yellow sandy clay | 7½ | 156 |
| | Green „ „ | 8 | 164 |
| | Red „ „ | 6 | 170 |
| [Thanet Sand, 27 feet] | Dead sand | 7 | 177 |
| | Green sand | 20 | 197 |
| Chalk | | 254 | 451 |

## Chelsea.

### 1.—Public Baths, Manor Street, King's Road, near Town Hall, 1906.

London Map 10 N.E. 28 feet above Ordnance Datum.

Dr. L. C. Parkes, *Journ. R. San. Inst.*, vol. xxvii., no. 5, pp. 271, 272 (1906)

Steel tube of 13½ inches diameter to 5 feet down in the Chalk. Begun 14th September, 1905, and boring ceased 24th February, 1906.

After reaching water in the flints above the Chalk, there was water all the way down. Water stands 120 feet down.

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| Soil | | 2 | 6 | 2 | 6 |
| River Drift, 22¼ feet | Sand and gravel ... ... nearly | 16 | 10 | 19 | 4 |
| | Gravel, water-bed ... ... | 4 | 0 | 23 | 4 |
| | Brown clay and gravel ... ... | 1 | 6 | 24 | 10 |
| London Clay, 148½ feet | Brown clay ... ... ... ... | 0 | 6 | 25 | 4 |
| | Blue clay, with six layers of clay-stone [septaria], two a foot thick, the rest six inches ... ... ... ... | 143 | 0 | 168 | 4 |
| | Basement-bed. Sand shells and pebbles | 5 | 0 | 173 | 4 |
| Reading Beds, 47 ft. | Mottled clay ... ... ... ... | 43 | 6 | 216 | 10 |
| | Dead sand and pebbles... ... ... | 3 | 6 | 220 | 4 |
| Thanet Sand, 45½ feet | Dead green sand ... ... ... | 7 | 0 | 227 | 4 |
| | Dead sand ... ... ... ... | 37 | 6 | 264 | 10 |
| | Green flints ... ... ... ... | 1 | 0 | 265 | 10 |
| Upper Chalk ... ... ... ... ... ... | | 197 | 11 | 463 | 9 |

### 2.—Bowden's Brewery, King's Road.

London Map 11 N.W.

Made by S. F. Baker & Son; communicated by Wm. Bradford.

Sunk well 136 feet, 5-inch bore 279 feet. Water-level 51 feet from surface.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| To base of London Clay ? ... ... ... ... | | — | 158 |
| [Reading Beds] | Coloured clay ... ... ... ... | 43 | 201 |
| | Fine clay ... ... ... ... | 3½ | 204½ |
| [Thanet Sand] | Green sand ... ... ... ... | 43½ | 248 |
| | Pebbles [?] and flints ... ... ... | 1½ | 249½ |
| Chalk and flints ... ... ... ... ... ... | | 166 | 415 |

## City Road.

London Map 7 N.E.

1.—THE ALEXANDRA TRUST, Baldwin Street, 200 yards North of St. Luke's Hospital, 1899.

61 feet above Ordnance Datum.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

Water-level 137 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Basement | | — | 9 |
| [River Gravel] | Ballast | 8 | 17 |
| [London Clay, 49 feet] | Brown clay and stones | 3 | 20 |
| | Blue clay | 45 | 65 |
| | Sandy clay | 1 | 66 |
| [Reading Beds, 52 feet] | Sharp sand | 2 | 68 |
| | Mottled clay | 10 | 78 |
| | Sandy clay | 19 | 97 |
| | Sandy clay, pebbles and clay | 21 | 118 |
| Thanet Sand | | 32 | 150 |
| Chalk and flints | | 161 | 311 |

2.—MESSRS. LIPTON'S, Gayton Street, 1899.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

Water-level 137 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Road-level | | — | 5 |
| [River Gravel] | Ballast | 15 | 20 |
| [London Clay, 50 feet] | Blue clay and septaria | 41 | 61 |
| | Sandy clay | 2 | 63 |
| | Blue clay | 7 | 70 |
| [Reading Beds, 43 feet] | Mottled clay | 9 | 79 |
| | Loamy clay | 17 | 96 |
| | Clay and pebbles | 5 | 101 |
| | Green sandy loam | 7 | 108 |
| | Loam and pebbles | 5 | 113 |
| [Thanet] | Sand, very hard | 34 | 147 |
| Chalk and flints | | 159 | 306 |

3.—MESSRS. LIPTON, Old Street.

About 60 feet above Ordnance Datum.

Communicated by A. WILLIAMS & Co.

Water-level 124 feet down. Supply estimated 2,000 gallons per hour.

Lined with 160 feet of 6-inch internal diameter tube, top level with surface.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Gravel and clay | | 8 | 8 |
| [London Clay] | Blue clay and clay stone | 6½ | 14½ |
| | Blue clay | 46½ | 61 |
| [Reading Beds] | Mottled clay | 17 | 78 |
| | Grey sand | 3 | 81 |
| | Sand and mottled clay | 8½ | 89½ |
| | Hard pebbles and sand | 4 | 93½ |
| | Hard green sand | 16 | 109½ |
| Grey Thanet Sand | | 26 | 135½ |
| Sand, flints and chalk | | 164½ | 300 |

## Edmonton. Pegamoid Works, De Ritter's.

Made and communicated (1901) by Messrs. Isler & Co.

Lined with 145 feet of tubes, of 6 inches diameter, 3 feet down.

Water-level 10 feet down.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Well (the rest bored) ... ... ... ... ... | — | 8 |
| [River Gravel] Ballast... ... ... ... ... | 6 | 14 |
| Blue [London] clay ... ... ... ... ... | 46 | 60 |
| [Reading Beds] { Mottled clay ... ... ... ... | 52 | 112 |
| [Reading Beds] { Blue clay and sand ... ... ... | 9 | 121 |
| Green [Thanet] sand ... ... ... ... ... | 18 | 139 |
| Chalk ... ... ... ... ... ... ... | 161 | 300 |

## Enfield.

### 1. Brims-down Park, 1896.

Made and communicated by Messrs. Tilley.

To Chalk (the section of the beds above mislaid) 79 feet.

### 2. Enfield Chase, on road to Ferry Hill, over 1¼ miles westward of cross-roads in town (near church and station), 1903.

Made and communicated by Mr. A. E. Nunn, of Tenterden.

Shaft 320 feet, with headings at 300 feet.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Soil ... ... ... ... ... ... ... | 2 | 2 |
| Clay and marl ... ... ... ... | 22 | 24 |
| Black sand ... ... ... ... | 3 | 27 |
| Clay ... ... ... ... | 3 | 30 |
| [? London Clay] { Strong blue sandy clay, with silicate of soda. Fossil bivalves and wood ... | 9 | 39 |
| [? London Clay] { Strong blue clay, approaching a shell-formation. Fossil bivalves ... ... | 6 | 45 |
| [? London Clay] { Dark brown silt ... ... ... ... | 6 | 51 |
| [? London Clay] { Hard sandstone rock, mixed with granite boulders [?] ... ... ... | 7 | 58 |
| [Reading Beds] { Light-coloured sandy loam (6 ft. & 2 ft.) | 8 | 66 |
| [Reading Beds] { Dark sandy loam ... ... ... | 4 | 70 |
| [Reading Beds] { Dark sandy loam with oyster-shells and pebbles ... ... ... ... | 16 | 86 |
| [? Thanet Sand] { Sharp sandy loam (1½ and 14 ft.) ... | 15½ | 101½ |
| [? Thanet Sand] { Flints ... ... ... ... ... | 1 | 102½ |
| Chalk ... ... ... ... ... ... ... | 220½ | 323 |

### 3. Hadley Road. Trial-hole, 1901.

Made and communicated by Messrs. Tilley.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil | | 3 | 3 |
| [River Drift?] | Gravel and clay | 2½ | 5½ |
| [London Clay] | Sandy clay | 9½ | 15 |
| | Blue clay | 14 | 29 |
| [Woolwich and Reading Beds, 45 feet] | Dark sand and water | 8 | 37 |
| | Mottled clay | 6 | 43 |
| | Light-coloured sand loam | 4 | 47 |
| | Red sand | 3 | 50 |
| | Dark sandy loam | 16 | 66 |
| | Sand and shells | 1½ | 67½ |
| | Dark loamy sand | 6½ | 74 |
| [? Woolwich and Thanet Beds] | Black [flint] pebbles, sand and water | 9 | 83 |
| | Sharp sand | 8 | 91 |
| | Flints | 1 | 92 |
| Chalk | | 6 | 98 |

### Feltham, near the Station. Messrs. Pritchett & Gold, 1907.

Boring, communicated by Messrs. Le Grand and Sutcliff.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [River] Gravel | | 10 | 10 |
| [London Clay, 294½ feet] | Brown clay | 1 | 11 |
| | Blue clay and septaria. A little sandy below 285 feet | 283 | 294 |
| | [Basement bed] Sandy clay | 7½ | 301½ |
| | [Basement bed] A few black [flint] pebbles | | |
| | [Basement bed] Sandy clay | 3 | 304½ |
| [Reading Beds, 90½ feet] | Mottled clay | 61½ | 366 |
| | Sand | 2½ | 368½ |
| | Mottled clay | 8½ | 377 |
| | Loamy sand [? Thanet] | 20 | 397 |
| Chalk and flints, soft | | 250 | 647 |
| Grey chalk | | 53 | 700 |

### Finsbury Square. Royal London Friendly Society, 1903.

London Map 7 S.E. 56 feet above Ordnance Datum.

*Builder*, vol. lxxxv., No. 3172, p. 529 (21st Nov., 1903).

Lined boring of 6 inches internal diameter.

Yield 2,000 gallons an hour.

| | | Thickness | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Blue [London] clay | | 68 | 68 |
| [Reading Beds, 56 feet] | Mottled clay | 16 | 84 |
| | Mottled clay, sand and hard pebbles | 10 | 94 |
| | Hard pebbles and green sand | 8 | 102 |
| | Hard green sand and pebbles | 22 | 124 |
| [Thanet Sand] | Grey sand | 29 | 153 |
| | Pebbles [flints] | 1 | 154 |
| Chalk and flints | | 296 | 450 |

There seems to be an excessive thickness of the "bottom-bed" of the Reading Beds (30 feet of green sand, with pebbles); possibly some Thanet Sand has been included.—W.W.

## Finsbury Circus. Salisbury House, London Wall, 1903.

London Map 7 S.E. Street about 47 feet above Ordnance Datum.

An account was published in the *Builder*, *Daily News*, *Daily Express*, and *Daily Chronicle*. The account in the *Builder* in January, 1904, gives the water-level as 140 feet down; the others, published a year earlier, give it as 123 feet down: this suggests that the level had fallen somewhat.

Two boreholes were made 7¼ inches in diameter, and the yield is 6,000 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [Thames Gravel] | Grey ballast ... ... ... | 3 | 3 |
| [London Clay] | Dark grey clay ... ... ... | 36 | 39 |
| | Dark grey clay and stones ... ... | 24 | 63 |
| | Grey sand and mottled clay ... | 2 | 65 |
| | Dark grey clay ... ... ... | 47 | 112 |
| [Reading Beds] | Mottled clay ... ... ... ... | 31 | 143 |
| | Mottled clay and hard pebbles ... | 3 | 146 |
| | Green sand and pebbles ... ... | 17 | 163 |
| [Thanet Sand] | Hard grey sand ... ... ... | 11 | 174 |
| | Live grey sand ... ... ... | 28 | 202 |
| | Black pebbles [flints] ... ... | 2 | 204 |
| Chalk and flints... ... ... ... ... ... | | 246 | 450 |

## Fulham.

London Map 10 N.E.

### 1. Electric Light Works, Townmead Road.

15 feet above Ordnance Datum.

Made and communicated by Messrs. A. C. Potter & Co.

The borehole of 9½ inches diameter.

Good supply of water.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Pit in Made Ground (the rest bored) ... ... | | — | 10 |
| Soil ... ... ... ... ... ... ... | | 9 | 19 |
| [River Drift]. | Sand and ballast ... ... ... | 10½ | 29½ |
| London Clay ... ... ... ... ... ... | | 130½ | 160 |
| Woolwich and Reading Beds ... ... ... ... | | 59 | 219 |
| Thanet Sand ... ... ... ... ... ... | | 31½ | 250½ |
| [Upper Chalk] | Chalk and flints (very numerous) | 229 | 479½ |
| | Chalk ... ... ... ... | 21 | 500½ |

2. PUBLIC BATHS. Just westward of St. John's Church, Walham Green, 1900.

16 feet above Ordnance Datum.

Two wells. Made and communicated by Messrs. A. C. POTTER & Co.

Western boring, near Hartismere Road. Chalk reached at 248 feet.

Eastern boring, near Melmoth Place. Chalk reached at 249 feet.

Still water-level 100 feet down.

| Eastern Boring. | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | 10 | 10 |
| [River Drift] Sand and ballast [gravel] ... ... | 21 | 31 |
| London Clay and claystones ... ... ... ... | 136 | 167 |
| Woolwich and Reading Beds ... ... ... ... | 37 | 22 |
| Thanet Sand ... ... ... ... ... ... | 25 | 249 |
| [Upper and Middle Chalk] Chalk and flints ... ... ... | 240 | 489 |
| [Upper and Middle Chalk] Chalk ... ... ... ... | 194 | 683 |
| [Upper and Middle Chalk] Grey [? damp] chalk ... ... | 17 | 700 |

Flints were very numerous; but the chalk was of a very dense nature, yielding very little water.

An account from Mr. H. D. PEARSON differs in details, and may refer to the western boring, in which the made ground is said to be a foot less.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Soil, sand and ballast ... ... ... ... ... | 30 | 30 |
| London Clay ... ... ... ... ... ... | 135 | 165 |
| [Reading Beds, 68 feet] Shells and mottled clay [? partly basement-bed of London Clay] ... | 10 | 175 |
| [Reading Beds, 68 feet] Woolwich and Reading Beds ... | 30 | 205 |
| [Reading Beds, 68 feet] Clay sand and ballast in alternate layers ... ... ... ... | 28 | 233 |
| Thanet Sand ... ... ... ... ... ... | 17 | 250 |
| [Upper and Middle Chalk] Chalk and flints, with vertical cleavage [jointing] ... ... | 130 | 380 (given as 378) |
| [Upper and Middle Chalk] Chalk and flints, not showing cleavage or stratification ... | 82 | 462 (given as 460) |
| [Upper and Middle Chalk] Chalk and flints, showing inclined cleavage and stratification ... | ? 30 | 492 |
| [Upper and Middle Chalk] Chalk ... ... ... ... ... | ? 50 | 542 |
| [Upper and Middle Chalk] Carried deeper, to ... ... ... | | 701 |

## Hackney.

### 1. Ash Grove, Southern side of Victoria Park. Messrs. Bush & Co.

About 50 feet above Ordnance Datum.

Made and communicated by Messrs. Isler & Co.

Lined with 140 feet of tubes, of 13½ inches diameter, 2 feet down.

Water-level 105 feet down. Supply 2,000 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Dug well ... ... ... ... ... ... ... | | — | 12 |
| [River Gravel] Ballast ... ... ... ... | | 3½ | 15½ |
| Blue [London] clay ... ... ... ... ... | | 51 | 68½ |
| [Blackheath Beds ?] Pebbles ... ... ... | | 13½ | 80 |
| [Reading Beds] | Green sand ... ... ... ... | 13 | 93 |
| | Pebbles ... ... ... ... | 9 | 102 |
| [Thanet Sand] | Hard stone ... ... ... ... | 17 | 119 |
| | Sandstone ... ... ... ... | 14 | 133 |
| [Upper Chalk] | Chalk and flints ... ... ... | 2 | 135 |
| | Chalk ... ... ... ... ... | 265 | 400 |

This reads as if the Blackheath Beds had cut off the upper part of the Reading Beds, or else the upper "pebbles" belong to the Reading Beds.

### 2. Baths, Lower Clapton Road and Urswick Road.

London Map 7 N.E.

60 feet above Ordnance Datum.

Made and communicated (1901) by Messrs. Isler & Co.

150 feet of tubes, of 13½ inches diameter, 10 feet down; 9 feet, of 18 inches diameter, 15 feet down.

Water-level 103 feet down. Supply 10,000 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Well (the rest bored). | Made ground and clay ... | — | 15 |
| [London Clay] | Blue clay ... ... | 32 | 47 |
| | Sandy loam ... ... | 5 | 52 |
| [Reading Beds, 43 feet] | Mottled clay ... ... | 23 | 75 |
| | Green[?sand with] pebbles | 7 | 82 |
| | Hard green sand ... | 13 | 95 |
| [Thanet Sand, 43 feet] | Grey sand ... ... | 30 | 125 |
| | Dark sand ... ... | 13 | 138 |
| Chalk | Chalk ... ... ... | 7 | 145 |
| | Chalk and flints... ... | 235 | 380 |
| | Grey chalk ... ... | 21 | 401 |

## Hadley. LAUNDRY. Trial-boring.

Water-level 318 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| London Clay ... ... ... ... ... ... | | 274½ | 274½ |
| [Reading Beds] | Coloured [mottled] clay ... | 23½ | 298 |
| | Gravels [? sand and pebbles] ... | 27 | 325 |
| Chalk ... ... ... ... ... ... ... | | 131½ | 456½ |

## Hampstead. ELECTRIC LIGHT STATION, Lithos Road, Finchley Road, at the western end of the yard, between railways, 1901.

London Map 6 N.E.

Communicated by Mr. G. H. COTTAM and notes from specimens.

Boring of 8½ inches diameter. About 172 feet above Ordnance Datum.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay, including surface-wash] | Clay and stones [brownish clay and flint pebbles] ... ... ... | 7½ | 7½ |
| | Yellow clay [brown, with a piece of selenite] ... ... ... ... | 24½ | 32 |
| | London blue clay [brown and grey] | 208 | 240 |
| [Reading Beds, 50 feet] | Coloured clays [various beds of mottled, brown, grey, red and purple] ... ... ... ... | 33 | 273 |
| | Sand and pebbles [flints, some jaspery] ... ... ... ... | 4 | 277 |
| | Green sand and pebbles ... ... | 13 | 290 |
| [Thanet Sand 26 feet] | Thanet sands [fine buff] ... ... | 25 | 315 |
| | Green flints ... ... ... | 1 | 316 |
| Chalk [and flints] ... ... ... ... ... | | 265 | 581 |

Between 480 and 500 feet the tools slipped through more easily than before. Water had been standing at about 229 feet down and suddenly rose to about 225; but as much as 1,000 gallons an hour could not be got.

A charge of 16 lbs. of dynamite was exploded at about 480 feet, and slots were cut in the steel pipe in the 4 feet bed of sand and pebbles, but without beneficial result.

## Harefield. SPRINGWELL.

No. 1 published in "The Geology of London,"

| 2. Water overflows. | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Shaft, through gravel to solid chalk, the rest bored | — | 20 |
| Chalk with flint ... ... ... ... ... ... | 64 | 84 |
| Grey chalk with hard stone ... ... ... ... | 11 | 95 |
| Grey chalk with a little flint ... ... ... ... | 17 | 112 |
| Grey chalk without flint ... ... ... ... | 24 | 136 |
| Grey chalk with a little flint ... ... ... ... | 34 | 170 |
| Grey chalk without flint ... ... ... ... | 4 | 174 |
| Very stiff [? firm] grey chalk ... ... ... ... | 8 | 182 |
| Very soft grey chalk ... ... ... ... ... | 10 | 192 |

| 3. Water overflows. | Thickness. | D |
|---|---|---|
| | Ft. | |
| Shaft, through gravel to solid chalk ... ... ... | — | |
| Very hard chalk and flint ... ... ... ... | 56 | |
| Very hard chalk; no flint ... ... ... ... | 22 | 1 |
| Very hard grey chalk with 7 inches of blue clay at top; no flint ... ... ... ... ... ... | 7 | 1 |

Of these borings one is between Springwell Lock and the rive
others are within the enclosure of the Springwell Pure Drinking Wa

## Harrow. GREENHILL LAUNDRY, 1897.

Made and communicated by Messrs. DUKE and OCKENDEN.

Shaft 16 feet, the rest bored. Water-level 118 feet down.

| | | Thickness. | D |
|---|---|---|---|
| | | Ft. | |
| [London Clay] | Clay ... ... ... ... ... | 87 | |
| | Hard stone ... ... ... ... | 6 | |
| [Reading Beds, 52 feet] | Reddish clay and stone ... ... | 7 | 1 |
| | Red sandstone [? firm sand]... ... | 15 | 1 |
| | Running sand ... ... ... ... | 23 | 1 |
| | Sandstone [? firm sand] ... ... | 7 | 1 |
| [Upper Chalk, 139 feet] | Chalk and flints ... ... ... | 105 | 2 |
| | Running sand with vein of stone ... | 7 | 2 |
| | Chalk and flints ... ... ... | 27 | 2 |

## Holborn. METROPOLITAN ELECTRIC SUPPLY CO.

Kingsway. About centre of western side.

London Map 7 S.W. 68 feet above Ordnance Datum.

Lined with 10-inch tube from 5 feet below surface. Water-leve
167 feet down.

| | | Thickness. | De |
|---|---|---|---|
| | | Ft. | |
| Clay [? London] ... ... ... ... ... ... | | 4 | |
| [London Clay] | Blue clay ... ... ... ... | 79½ | 8 |
| | Sandy clay ... ... ... ... | 30 | 11 |
| [Woolwich and Reading Beds, 52 feet] | Coloured clays ... ... ... | 36 | 14 |
| | Mottled clay ... ... ... ... | 4 | 15 |
| | Stone ... ... ... ... ... | 4½ | 15 |
| | Sandy clay and pebbles ... ... | 4½ | 16 |
| | Green sand, clay and pebbles ... | 3 | 16 |
| [Thanet Sand] | Dead sand ... ... ... ... | 13 | 17 |
| | Green sand ... ... ... ... | 4 | 18 |
| Chalk ... ... ... ... ... ... ... | | 250 | 43 |

The surface of the Chalk should be 132 feet below sea-level.

**Holloway.** Brewery Road, MESSRS. CROSSE & BLACKWELL'S VINEGAR FACTORY. Between York Road and Caledonian Road, 200 yards south of the Cattle Market.

London Map 7 N.W. Height above Ordnance Datum about 130 feet.
Made and communicated by Messrs. ISLER & Co.
Water-level 210 feet down. Supply 3,500 gallons an hour (minimum).

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Pit, in Made Ground, the rest bored, 8½ inches diameter ... ... ... ... ... ... ... | | — | 20 |
| [London Clay] | Yellow clay ... ... ... ... | 12 | 32 |
| | Yellow and blue clay ... ... | 13 | 45 |
| | Blue clay ... ... ... ... | 103 | 148 |
| [Reading Beds, 74½ feet] | Mottled clay ... ... ... ... | 26 | 174 |
| | Yellow clay ... ... ... ... | 7 | 181 |
| | Yellow sandy clay ... ... ... | 6½ | 187½ |
| | Yellow loamy sand ... ... ... | 3 | 190½ |
| | Dead sand ... ... ... ... | 6½ | 197 |
| | Dead green sand ... ... ... | 6 | 203 |
| | Dark sand ... ... ... ... | 7 | 210 |
| | Sand and pebbles ... ... ... | 12½ | 222½ |
| [Thanet Sand, 5 feet] | Dead sand ... ... ... ... | 3½ | 226 |
| | Green sand, flints ... ... ... | 1½ | 227½ |
| [Upper Chalk, 222½ feet] | Chalk ... ... ... ... ... | 15½ | 243 |
| | Chalk and flints ... ... ... | 69 | 312 |
| | Hard chalk ... ... ... ... | 6 | 318 |
| | Chalk ... ... ... ... ... | 8 | 326 |
| | Chalk and flints ... ... ... | 39 | 365 |
| | Chalk ... ... ... ... ... | 6 | 371 |
| | Chalk and flints ... ... ... | 16 | 387 |
| | Hard flint ... ... ... ... | 1½ | 388½ |
| | Hard rock ... ... ... ... | ½ | 388¾ |
| | Hard flint ... ... ... ... | ¼ | 389¼ |
| | Chalk and flint ... ... ... | 56¾ | 446 |
| | Chalk... ... ... ... ... | 4 | 450 |

**Hornsey.** HORNSEY BREWERY, MESSRS. CAFFYN, Clarendon Road, 250 yards north of Hornsey Station, G.N.R., eastern side of Line, 1898 ?).

London Map 3 N.W. Height above Ordnance Datum, 85 feet.
Made and communicated by Messrs. ISLER.
Lined with 184 feet of tube, 5 inches in diameter.
Water-level 11 feet down. Supply 1,000 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Well [? old], the rest bored ... ... ... ... | | — | 5 |
| [London Clay] | Yellow clay ... ... ... ... | 15 | 20 |
| | Yellow clay and stone ... ... | 9 | 29 |
| | Blue clay ... ... ... ... | 83 | 112 |
| | Yellow clay ... ... ... ... | 7 | 119 |
| [Reading Beds, 27 feet?] | Grey mottled clay ... ... ... | 2 | 121 |
| | Sandy clay ... ... ... ... | 2 | 123 |
| | Dead sand ... ... ... ... | 17 | 140 |
| | Clay and shells ... ... ... | 6 | 146 |
| [Thanet Sand, 22 feet] | Dead sand ... ... ... ... | 12 | 158 |
| | Black pebbles [flints ?] and sand ... | 10 | 168 |
| Chalk and flints... ... ... ... ... ... | | 112 | 280 |

**Houndsditch.** Gravel Lane (Torrplace). For the Commissioners of Sewers, City of London, 1888.

London Map 7 S.E. Height above Ordnance Datum, 48½ feet.

Details, down to the depth of 123 feet, were published in The Geology of London, vol. ii., p. 118. The further details were given in "An Account of the Artesian Well . . . " by W. HAYWOOD, published in 1893.

Cylinders and shaft. Water-level in the gravel, 24 feet 11 inches.

At the depth of 350 feet the yield was 900 gallons an hour; at 450 feet it increased to 2,000 gallons; at the last, pumping for two consecutive hours gave a yield of about 70,000 gallons in 24 hours, or nearly 3,000 gallons an hour.

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| [Made Ground, &c.] | Loose brick-rubbish ... ... ... | 4 | 6 | 4 | 6 |
| | Made ground ... ... ... ... | 9 | 6 | 14 | 0 |
| | Dark top-soil, alluvial clay ... ... | 1 | 10 | 15 | 10 |
| [River Drift, nearly 16 feet] | Alluvial brick-earth (mean) ... | 1 | 10 | 17 | 8 |
| | Gravel and sand, with layers of yellow sand at 20½ to 21, and 24¼ to 24½, and gravel coarser from 22 to 23½ ... ... ... ... | 13 | 7 | 31 | 3 |
| | Fine gravel, dark stained at base ... | 0 | 6 | 31 | 9 |
| [London Clay] | Yellow clay ... ... ... about | 0 | 11 | 32 | 8 |
| | Blue clay, variable in character, with septaria in many places, especially in the lower part. Various fossils in the upper part [shells and plants]. Sand-veins in the lower part, especially near the base. Water at the depths of 58½ and just below 95 feet from sand-pockets ... ... ... | 90 | 8 | 123 | 4 |
| | [Basement-bed] Clay with sand-partings and occasional black (flint) pebbles. Some green grains and lignite ... ... ... | 6 | 8 | 130 | 0 |
| [?Blackheath or Woolwich Beds] | Black sand, with pebbles, pyrites, pyritized wood and lignite. Water | 16 | 11 | 146 | 11 |
| [Woolwich and Reading Beds] | Mottled clay ... ... ... ... | 2 | 11 | 149 | 10 |
| | Dark sandy clay ... ... ... | 4 | 0 | 153 | 10 |
| | Firm, hard, blue clay, with occasional shells... ... ... ... | 3 | 2 | 157 | 0 |
| | Laminated clay, with occasional shells... ... ... ... ... | 3 | 8 | 160 | 8 |
| | Mottled clay ... ... ... ... | 0 | 6 | 161 | 2 |
| | Laminated clay, with occasional shells... ... ... ... ... | 2 | 1 | 163 | 3 |
| | Mottled clay ... ... ... ... | 5 | 8 | 168 | 11 |
| | Small pebbles; pyrites ... ... | 3 | 0 | 171 | 11 |
| | Rock, with pebbles and shells (110 days getting through this) ... | 5 | 9 | 177 | 8 |
| | Green sand, with pebbles and a few shells... ... ... ... ... | 9 | 2 | 186 | 10 |

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| [Thanet Sand, 40¾ feet] | Light-coloured sand, with thin layers of blue clay... ... ... | 8 | 8 | 195 | 6 |
| | Thanet sand ... ... ... ... | 32 | 2 | 227 | 8 |
| | Flints (thin) ... ... ... / Chalk and flints ... ... | 19 | 6 | 247 | 2 |
| | Flints ... ... ... ... ... | 2 | 6 | 249 | 8 |
| | Chalk, soft ... ... ... ... | 16 | 4 | 266 | 0 |
| | Flints (9 inches); chalk with loose flints; hard chalk ... ... ... | 4 | 0 | 270 | 0 |
| [Upper Chalk, 283¾ feet] Fissures are noted at many depths. | Chalk, with 9 inches of flints at top, 12 inches at 274 feet, 9 inches at 281 and 302½ feet; then hard; then with loose flints; 18 inches of flints at 327 feet; 9 inches of flints at 341 feet; then with loose flints; 14 inches of flints at 344 feet; then with loose flints; 9 inches of flints at 357 feet; then hard; 6 inches of flints at 370 feet, and 12 inches at 378 feet; then with loose flints; 9 inches of flints at 402½ feet, with loose flints just beneath; then hard; then softer; then with loose flints; then hard; then with loose flints; 12 inches of flints at 476 and 9 inches at 481¼ feet, with loose flints just beneath; 9 inches of flints at 495½ feet; then with loose flints; then hard; 6 inches of flints at 504½ feet; then with loose flints; at last becoming grey ... ... | 242 | 6 | 512 | 6 |

## Hyde Park Hotel (Albert Gate).

London Map 7 S.W. Height above Ordnance Datum, 37 feet.

*Water*, vol. vi., no. 63, p. 117 (1904). (? Made by ISLERS.)

Water-level 50 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Pit (the rest bored) ... ... ... ... ... | | — | 11 |
| [River Drift] | Clay and sand... ... ... ... | 6 | 17 |
| | Sharp sand ... ... ... ... | 3 | 20 |
| | Ballast [gravel] ... ... ... | 9 | 29 |
| [London Clay, 173 feet] | Blue clay ... ... ... ... | 134 | 163 |
| | Sandy clay ... ... ... ... | 39 | 202 |
| [Reading Beds, 66 feet] | Mottled clay ... ... ... ... | 6 | 208 |
| | Grey sand ... ... ... ... | 6 | 214 |
| | Mottled clay and pebbles ... ... | 50 | 264 |
| | Dead sand and pebbles ... ... | 4 | 268 |
| [? Thanet] Green sand and flints ... ... ... | | 16 | 284 |
| [Upper] Chalk and flints ... ... ... ... | | 166 | 450 |

Although not made for the purpose of getting water, the following section may be of interest:—

## Isle of Dogs (Greenwich Ferry Company), 1888?

Geological Map 1 S.W.

Communicated by Mr. G. J. Cross, Managing Director.

Two shafts of 10 feet diameter for the cylinders.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Foreshore shingle | | 10 | 10 |
| [Alluvium] Clay | | 13 | 23 |
| [River Gravel] | Coarse ballast | | |
| | Fine ballast | 12½ | 35½ |
| | Coarse ballast | | |
| [Thanet (? part Woolwich) Beds] | Hard green sand | 25 | 60½ |
| | White sand | 30 | 90½ |
| | Flints | ½ | 91 |
| Chalk with layers of flints | | 22 | 113 |

## Kensal Green (Gas Light & Coke Co.). Between Railway and Canal.

London Map 6 N.E. About 90 feet above Ordnance Datum.

Made and communicated by A. C. Potter & Co.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground | | 10 | 10 |
| [London Clay] | Red clay | 18 | 28 |
| | Blue clay | 220 | 248 |
| [Reading Beds] | Mottled clays | 40 | 288 |
| | Conglomerate | 8 | 296 |
| | Sand and pebbles | 8 | 304 |
| [Thanet Sand] | Light-grey sand | 3 | 307 |
| | Light-grey sand and pebbles | 3 | 310 |
| | Thanet sand | 9 | 319 |
| | Green flints | 1 | 320 |
| Chalk | | 330 | 650 |

## Kentish Town (St. Pancras Baths, Prince of Wales Road, 200 yards west of Kentish Town Road, 1904).

London Map 7 N.W. Height above Ordnance Datum about 100.

Communicated by Mr. T. W. Aldwinckle.

Two borings, about 100 feet apart.

*Boring No. 1.*

Shaft about 8 feet, the rest bored.

Pipes of 16 inches diameter, from 3 to 147 feet down.

„ 14½ „ „ „ 2½ to 213 „ „

Water-level 180 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay] | Brown clay ... ... ... ... | 20 | 20 |
| | Blue clay and septaria ... ... | 109 | 129 |
| [Reading Beds] | Mottled clay ... ... ... ... | 41 | 170 |
| | Hard sandy clay and pebbles ... | 3 | 173 |
| | Clay and pebbles conglomerate ... | 8 | 181 |
| | Hard sand and mundic ... ... | 3½ | 184½ |
| | Hard sand ... ... ... ... | 6½ | 191 |
| | Pebbles and sand ... ... ... | 1½ | 192½ |
| | Pebbles ... ... ... ... | 1½ | 194 |
| Thanet Sand | ... ... ... ... ... | 9 | 203 |
| [Upper Chalk] | Chalk and flints ... ... ... | 9 | 212 |
| | Sticky chalk and flints ... ... | 7 | 219 |
| | Hard, dense sticky chalk and flints... | 31½ | 250½ |
| | Chalk and flints ... ... ... | 65½ | 316 |
| | Flint ... ... ... ... ... | 3 | 319 |
| | Hard chalk ... ... ... ... | 14 | 333 |
| | Hard chalk and flints ... ... | 22½ | 355½ |
| | Chalk and flints ... ... ... | 94½ | 450 |

Perhaps the top three beds classed as Reading Beds may belong to the London Clay.

*Boring No. 2* is 13½ inches in diameter.

An account of this, by Mr. C. Isler, appeared in the *Standard* of May 30th, 1907, the section being as follows:—

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground | ... ... ... ... ... ... | 1 | 1 |
| [London Clay] | Brown clay ... ... ... ... | 20 | 21 |
| | London clay (blue) ... ... ... | 104 | 125 |
| [Reading (and ? Thanet) Beds] | Mottled clay ... ... ... ... | 43 | 168 |
| | Mottled clay, sand, and pebbles ... | 3 | 171 |
| | Green sand ... ... ... ... | 3 | 174 |
| | Grey sand ... ... ... ... | 26 | 200 |
| | Grey sand and pebbles ... ... | 5½ | 205½ |
| Chalk and flints... | ... ... ... ... ... ... | 275 | 480½ |

The test-pumping in Bore 1 gave a yield of from 13,000 to 15,782 gallons an hour; in Bore 2 of from 13,680 to 14,262. When pumping was carried on from both the yield was 26,000, without putting any strain upon

wells or lowering the water-levels beyond the level resulting from pumping one bore at a time. Later the yield, with the wells in regular working order, was 27,000 gallons an hour, the water being raised by air-lift.

The hardness of the water is not over 4°, and the temperature about 53° F.

**King's Cross.** THE TIMES LAUNDRY Co., York Road, close to King's Cross, 1900.

London Map 7 N.W. Height above Ordnance Datum about 60 feet.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.

Water-level 139 feet down. In November, 1901, 142 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil ... ... ... ... ... ... ... | | 10 | 10 |
| [London Clay, 57 feet] | Yellow clay ... ... ... ... | 6 | 16 |
| | Blue clay and septaria ... ... | 31½ | 47½ |
| | Fine sandy clay ... ... ... | 4½ | 52 |
| | Dark clay ... ... ... ... | 15 | 67 |
| [Reading Beds, 60 feet] | Mottled clay ... ... ... ... | 44½ | 111½ |
| | Mottled sandy clay ... ... ... | 9½ | 121 |
| | Grey sandy clay ... ... ... | 2 | 123 |
| | Grey sandy clay and pebbles ... | 4 | 127 |
| Grey [Thanet] sand ... ... ... ... ... ... | | 14 | 141 |
| Chalk and flints ... ... ... ... ... ... ... | | 159 | 300 |

**Millwall.** Ferry Street, Cubitts Town, close to river. MESSRS. PARRY.

London Map 12 N.W. Height above Ordnance Datum 10 feet.

Made and communicated by Messrs. ISLER & Co.

Lined with 65 feet of tubes, of 11½ inches diameter, 8 feet down; and 95 feet, of 10 inches diameter, 5 feet down.

Water-level 19 feet down. Supply 6,500 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [? Alluvium and Gravel] Ballast and clay ... ... | | 25 | 25 |
| [? River Drift] | Ballast [gravel] ... ... ... | 5 | 30 |
| | Sand ... ... ... ... ... | 5½ | 35½ |
| | Ballast [gravel] ... ... ... | 6 | 41½ |
| [? Reading Beds] Pebbles ... ... ... ... | | 1 | 42½ |
| [Thanet Sand] | Thanet sand ... ... ... ... | 45½ | 88 |
| | Green-coated flints ... ... ... | 6 | 94 |
| Grey [Upper] chalk and flints ... ... ... | | 156 | 250 |

The thickness of the bed with green-coated flints at the base of the Thanet Sand is exceptional.

## New Southgate (Great Northern Railway Co., 1900).

Made and communicated by Messrs. Le Grand and Sutcliff.

Water-level 167½ feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay] | Brown and blue clay ... ... | 11 | 11 |
| | Brown clay ... ... ... ... | 26 | 37 |
| | Blue clay and septaria ... ... | 81 | 118 |
| | [Basement-bed]. Grey sandy clay and shells ... ... ... ... | 3½ | 121½ |
| [Reading Beds, 39½ feet] | Mottled clay ... ... ... ... | 16 | 137½ |
| | Mottled and sandy clay ... ... | 12½ | 150 |
| | Green sandy clay and pebbles ... | 11 | 161 |
| [Thanet Sand] | Thanet sand ... ... ... ... | 17 | 178 |
| | Green flints ... ... ... ... | ⅔ | 178⅔ |
| Chalk and flints ... ... ... ... ... ... | | 271⅓ | 450 |

## Notting Hill.

London Map 6 S.E.

### 1. Latimer Road, Phœnix Brewery. Campbell, Johnstone & Co., 1898?

Bored and communicated by Messrs. Isler.

Lined with 230 feet of tubes, of 11½ inches diameter, 7 feet below surface.

Water-level 80 feet down. Supply 4,500 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [River Drift] | Red clay ... ... ... ... | 5 | 5 |
| | Clay and ballast ... ... ... | 1 | 6 |
| | Mixed clay and stones ... ... | 3 | 9 |
| | Sharp sand ... ... ... ... | 2 | 11 |
| | Sand ... ... ... ... ... | 2 | 13 |
| | Mixed clay ... ... ... ... | 2 | 15 |
| | Sharp sand ... ... ... ... | 1 | 16 |
| | Ballast [gravel] ... ... ... | 5 | 21 |
| [London Clay] | Claystones 1 foot, then blue clay ... | 127 | 148 |
| [Reading Beds, 52 feet] | Mottled clay ... ... ... ... | 42 | 190 |
| | Clay and mixed pebbles ... ... | 3 | 193 |
| | Mixed sand and pebbles ... ... | 7 | 200 |
| [Thanet Sand] | Green sand ... ... ... ... | 22 | 222 |
| | Green flints and chalk ... ... | 1 | 223 |
| [Upper Chalk, 177 feet] | White chalk and flints ... ... | 84 | 307 |
| | Hard chalk and flints ... ... | 58 | 365 |
| | Chalk and flints ... ... ... | 35 | 400 |

2. NORTHERN END OF PORTLAND ROAD, a turning out of Bays opposite Holland Gardens. NOTTING HILL BREWERY Co

Height above Ordnance Datum 35 feet.
Made and communicated by Messrs. ISLER & Co.
Lined with 120 feet of tubes of 13½ inches diameter, 10 feet down, an 235 feet, of 11½ inches diameter, 7 feet down.
Water-level 115 feet down. Supply 10,000 gallons an hour.

| | | Thickness. | D |
|---|---|---|---|
| | | Ft. | |
| Made ground ... ... ... ... ... ... | | 1 | |
| [London Clay] | Brown clay ... ... ... ... | 26 | |
| | London clay ... ... ... ... | 125 | 1 |
| [Reading Beds] Mottled clay ... ... ... ... | | 50 | 2 |
| [Thanet Sand, 30 feet] | Hard green sand ... ... ... | 26 | 2 |
| | Hard black sand ... ... ... | 3½ | 2 |
| | Green-coated flints ... ... ... | ½ | 2 |
| Chalk ... ... ... ... ... ... ... | | 168 | 4 |

## Ponders End.

### 1. ARBOR NURSERIES, MRS. SYDERHOLME'S, 1898.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.
Water-level 28 feet down.

| | | Thickness. | D |
|---|---|---|---|
| | | Ft. | |
| Well (the rest bored) ... ... ... ... ... | | — | |
| [River] Gravel ... ... ... ... ... ... | | 1 | |
| [Basement-bed of London Clay ?] Clay and shells | | 3 | |
| [Reading Beds] | Mottled clay ... ... ... ... | 2 | |
| | Grey sand ... ... ... ... | 9 | |
| | Grey sand and pebbles ... ... | 12 | |
| [Reading and Thanet] Dark sand (flowing at 57½ feet) | | 51½ | |
| Chalk and flints ... ... ... ... ... ... | | 36½ | 1 |

### 2. BUSH MILL NURSERY, MESSRS. LOW, 1898.

Made and communicated by Messrs. LE GRAND and SUTCLIFF.
Water-level 52½ feet down.

| | | Thickness. | D |
|---|---|---|---|
| | | Ft. | |
| Made ground ... ... ... ... ... ... | | 1 | |
| [River Drift] | Red clay ... ... ... ... | 13½ | |
| | Red gravel ... ... ... ... | 6½ | |
| [London Clay] | Red clay ... ... ... ... | 1 | |
| | Blue clay ... ... ... ... | 18 | |
| [Reading Beds, 63 feet] | Dark sand ... ... ... ... | 26 | |
| | Pebbles and dark sand ... ... | 2 | |
| | Dark sand ... ... ... ... | 3 | |
| | Green sand ... ... ... ... | 21½ | |
| | Sand and pebbles ... ... ... | 10½ | 1 |
| Dark [Thanet] sand ... ... ... ... ... | | 16½ | 1 |
| Chalk and flints ... ... ... ... ... ... | | 100½ | 2 |

## 3. Churchbury, Mr. Rochford's, 1901.

Made and communicated by Messrs. Le Grand and Sutcliff.

Water-level 37½ feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil | | ¾ | ¾ |
| [River Drift, 13¾ feet] | Brown sandy clay | 1½ | 2¼ |
| | Gravel | 2 | 4¼ |
| | Mottled sand | 1¼ | 5½ |
| | Gravel | 9 | 14½ |
| [? Basement-bed of London Clay] | Black sandy clay | 4¾ | 19¼ |
| | Grey sand and shells | 5 | 24¼ |
| [Woolwich and Reading Beds, 47¾ feet] | Mottled loam | 1¾ | 26 |
| | Light-grey sand | 10 | 36 |
| | Grey sand and pebbles | 11 | 47 |
| | Grey sand and thin layer of clay | 15½ | 62½ |
| | Sand, shells and pebbles and thin layers of clay | 9½ | 72 |
| Thanet Sand | | 18½ | 90½ |
| Chalk and flints | | 113 | 203½ |

## 4. Gasworks, 1901.

Made and communicated by Messrs. Tilley.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil | | 4 | 4 |
| [River] Gravel | | 11 | 15 |
| [London Clay] | Blue clay | 11 | 26 |
| | Dark sandy clay, little water | 7 | 33 |
| [Reading Beds, 48 feet] | Coloured [mottled] clay | 2 | 35 |
| | Hard grey sand | 10 | 45 |
| | Sand and [flint] pebbles | 1 | 46 |
| | Grey sand | 4 | 50 |
| | Sand and [flint] pebbles | 9 | 59 |
| | Black [flint] pebbles | 1½ | 60½ |
| | Green sand | 19½ | 80 |
| | Sand and [flint] pebbles | 1 | 81 |
| [Thanet Sand] | Grey sand, little water | 27 | 108 |
| | Green-coated flints, to Chalk | ½ | 108½ |

## 5. Messrs. Guiver and Lawson's Nursery, Hertford Road, 1898 (close to 9th milestone from London).

Made and communicated by Messrs. Le Grand and Sutcliff.

Water-level 26¼ feet down in 1898, 37½ in 1902.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | 1 | 1 |
| [River Drift] Sand and gravel ... ... ... | 3 | 4 |
| [River Drift] Gravel ... ... ... ... ... | 12 | 16 |
| Blue [London ?] clay ... ... ... ... ... | 3 | 19 |
| [Reading Beds] Mottled clay ... ... ... ... | 1 | 20 |
| [Reading Beds] Grey sand ... ... ... ... | 8 | 28 |
| [Reading Beds] Grey sand and pebbles ... ... | 5 | 33 |
| [Reading and Thanet] Sand and dark ... ... | 51 | 84 |
| Chalk and flints ... ... ... ... ... ... | 96 | 180 |

## 6. London Brick Co., 1898.

Made and communicated by Messrs. Le Grand and Sutcliff.

Water-level 53 feet down.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Well (the rest bored) ... ... ... ... ... | — | 42 |
| Blue sand and clay and woodwork ... ... ... | 3½ | 45 |
| [Reading Beds, 63½ feet] Mottled clay ... ... ... ... | 3½ | 49 |
| [Reading Beds, 63½ feet] Grey sand ... ... ... ... | 12 | 61 |
| [Reading Beds, 63½ feet] Sand and pebbles ... ... ... | 4 | 65 |
| [Reading Beds, 63½ feet] Sand ... ... ... ... ... | 1½ | 66½ |
| [Reading Beds, 63½ feet] Hard gravel ... ... ... ... | 3½ | 70 |
| [Reading Beds, 63½ feet] Sand ... ... ... ... ... | 20 | 90 |
| [Reading Beds, 63½ feet] Blue clay and sand ... ... ... | 10 | 100 |
| [Reading Beds, 63½ feet] Sand, clay and shells... ... ... | 9 | 109 |
| [? Thanet] Sand ... ... ... ... ... ... | 11 | 120 |
| Chalk and flints ... ... ... ... ... ... | 130 | 250 |

These sections show that the Reading Beds are at little depth at parts of Ponders End.

## Poplar. Messrs. Spratt's, Morris Rd., near S. Bromley Station.

London Map 8 S.W. Height above Ordnance Datum, 17 feet.

Made and communicated (1901) by Messrs. Isler & Co.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | | 8 | 8 |
| [River Gravel] ballast ... ... ... ... ... | | 17 | 25 |
| Blue [London] clay ... ... ... ... ... | | 53 | 78 |
| [? Blackheath or Woolwich Beds] | Black [flint] pebbles [? basement-bed of London Clay] ... ... ... | 2 | 80 |
| | Sand and shells ... ... ... | 2½ | 82½ |
| | Dark sand ... ... ... ... | 3 | 85½ |
| | Grey sand ... ... ... ... | 11 | 96½ |
| [Woolwich and Reading Beds] | Sandy clay ... ... ... ... | 1 | 97½ |
| | Clay and shells ... ... ... | 10 | 107½ |
| | Congealed [cemented] shells ... | 3 | 110½ |
| | Mottled clay ... ... ... ... | 8 | 118½ |
| | Green sand and [flint] pebbles ... | 14 | 132½ |
| Dark [Thanet] sand ... ... ... ... ... | | 46 | 179 |
| [Upper Chalk, 171 feet] | Chalk and flints ... ... ... | 91 | 270 |
| | Grey chalk ... ... ... ... | 12 | 282 |
| | Soft chalk ... ... ... ... | 68 | 350 |

## Potter's Bar. Barnet District Water Co., close to (and north of) the Railway Station. Trial-boring. 1895.

Communicated by Mr. T. H. Martin, Engineer to the Company.

310 feet above Ordnance Datum.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil ... ... ... ... ... ... ... | | ¾ | ¾ |
| [? Trace of Drift, or Wash] | Yellow clay ... ... ... ... | 4½ | 5¼ |
| | Ballast ... ... ... ... | ¾ | 6 |
| [London Clay, 83½ feet] | Yellow clay ... ... ... ... | 21 | 27 |
| | Blue clay, with clay-stones at the depths of 35-35½ and 41 to 41¾ feet ... ... ... ... ... | 59 | 86 |
| | Dark sand / Clay stone [? Basement-bed] ... ... | 3 | 89 |
| | ... | ½ | 89½ |
| [Reading Beds, 33 feet] | Mottled clay ... ... ... ... | 10 | 99½ |
| | Greenish sand ... ... ... ... | 13½ | 113 |
| | Sand and pebbles ... ... ... | 8 | 121 |
| | Sand, Thanet [?] ... ... ... | 1 | 122 |
| | Flints, to Chalk ... ... ... | ½ | 122½ |

The well (1896), 11¼ feet in diameter and 10 feet diameter in the Chalk, is 50 feet N.W. of the bore-hole, and its section differs in the following particulars:—

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| Yellow clay ... ... ... ... ... ... | 5½ | 6¼ |
| Ballast ... ... ... ... ... ... | ¾ | 6¾ |
| Yellow clay ... ... ... ... ... ... | 22¼ | 29 |
| Blue clay, with clay-stone at 34 to 34 feet 1 inch ... | 58 | 87 |
| Mottled clay ... ... ... ... ... ... | 9½ | 100 |
| To Chalk ... ... ... ... ... ... ... | — | 123 |
| Chalk. At first some flints in a bed right across; then only scattered. At 190-194 yellow and then a six-or eight-inch bed of flints across the well ... ... ... ... ... ... ... | — | 200 |

## **Regent's Park.** ZOOLOGICAL GARDENS. New Boring. 1899. Northern side of road close to the Canal Bridge, on top of the bank).

London Map 7 N.W. Height above Ordnance Datum 115 feet.

Sand got into the old bore-hole and made the pump useless. A new boring was made in the old well (finished 1899) and has been described by Dr. P. L. SCLATER, (*Quart. Journ. Geol. Soc.*, vol. lvi., pp. iv., v., 1900) from particulars supplied by the contractors (Messrs. ISLER & Co.), which are here reproduced, with additional remarks [from specimens].

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Old well 170 feet, concrete 8 feet ... ... ... | | — | 178 |
| [Reading Beds] | Grey sand [clayey, a few small bits of stone] ... ... ... ... | 1 | 179 |
| | Mottled clay [brown and grey] ... | 5 | 184 |
| | Green sand [clayey, mottled brown] | 9 | 193 |
| | Sand [brown, fine compacted] and pebbles [dark flint, of fair size] ... | 8 | 201 |
| [Thanet Sand] | Dead grey sand [fine, compacted] ... | 12 | 213 |
| | Flints [some green-coated] ... ... | 1 | 214 |
| [Upper Chalk] | Chalk [white] ... ... ... ... | 238 | 452 |
| | Grey chalk [nearly white] ... ... | 20½ | 472½ |

The specimens of sand are all lumps, ? compacted by boring-tools.

The yield was 4,500 gallons an hour.

## **Ruislip.** NORTHWOOD. MOUNT VERNON SANATORIUM. 1903.

Boring made and communicated by Messrs. DUKE and OCKENDEN.

10 feet of tubes of 15 inches diameter; 116 feet of 12 inches diameter, 2 feet into the Chalk; 202 of 10 inches diameter, to top.

Water-level 182 feet down. Yield 2,500 gallons an hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [? Drift] | Gravel sand and clay ... ... ... | 10 | 10 |
| [London Clay, 81 feet] | Clay ... ... ... ... ... | 21 | 31 |
| | Clay and stones ... ... ... | 38 | 69 |
| | Clay ... ... ... ... ... | 22 | 91 |
| [Reading Beds, 26 feet] | Sand ... ... ... ... ... | 7 | 98 |
| | Sandstone ... ... ... ... | 3 | 101 |
| | Hard sandstone ... ... ... | 9 | 110 |
| | Sand and gravel [pebbles ?] ... | 7 | 117 |
| Chalk and flints | ... ... ... ... ... | 333 | 450 |

The composition of the Reading Beds is unusual, and perhaps some of the lowest bed of clay may belong to this series.

## **St. James.** Carnaby Street, north of Golden Square. The Central Station of the St. James and Pall Mall Electric Lighting Co., 1904.

London Map 7 S.W. Height of street above Ordnance Datum about 80 feet.

Made by Messrs. H. C. POTTER and Co. Communicated by the COMPANY.

Top of well 14 feet below street-level. Yield 12,000 gallons per hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Concrete ... | ... ... ... ... ... ... | 5 | 5 |
| [River] Gravel | ... ... ... ... ... ... | 16 | 21 |
| [? London Clay] | London clay ... ... ... | 100 | 121 |
| | Dark dead sand ... ... ... | 10 | 131 |
| | Light-grey dead sand ... ... | 5 | 136 |
| | Light-yellow dead sand ... ... | 5 | 141 |
| [Reading Beds, 61 feet] | Light-coloured mottled clay ... | 30 | 171 |
| | Very dark mottled clay ... ... | 5 | 176 |
| | Light-green clay ... ... ... | 5 | 181 |
| | Dark mottled sand ... ... ... | 4 | 185 |
| | Light-coloured flecked sand ... | 6 | 191 |
| | Dark flecked conglomerate ... ... | 5 | 196 |
| | Light-coloured flecked conglomerate | 6 | 202 |
| [Thanet Sand] | Dark Thanet sand ... ... ... | 7 | 209 |
| | Green flints ... ... ... ... | ½ | 209½ |
| Chalk and flints | ... ... ... ... ... ... | 230 | 439½ |

## St. Mary Axe. Baltic Exchange.

London Map 7 S.E. Height above Ordnance Datum about 5

Made and communicated by Messrs. Isler & Co.

Lined with 40 feet of tubes, of 13½ inches diameter, 2 feet down, 220 feet, of 11½ inches diameter, a foot down.

Water-level 117 feet down. Supply 6,200 gallons an hou

| | | Thickness. |
|---|---|---|
| | | Ft. |
| Blue [London] clay ... ... ... ... ... | | 112 |
| [Reading Beds, 52 feet] | Mottled clay ... ... ... ... | 1 |
| | Green sand ... ... ... ... | 2 |
| | Grey sand ... ... ... ... | 3 |
| | Dark sand ... ... ... ... | 4½ |
| | Green sand ... ... ... ... | 1 |
| | Black rock ... ... ... ... | 20 |
| | Dark clay ... ... ... ... | 4 |
| | Streaky clay ... ... ... ... | 4½ |
| | Green sandy clay ... ... ... | 2 |
| | Green sand and pebbles ... ... | 10 |
| [Thanet Sand, 47 feet] | Green sand ... ... ... ... | 9 |
| | Loamy sand and pebbles [? brought down by tool] ... ... ... | 38 |
| [Upper] Chalk ... ... ... ... ... ... | | 239 |

## Soho. Messrs. Crosse & Blackwell's, between Soho and Charing Cross Road.

London Map 7 S.W. Street-level 85 feet above Ordnance Da

E. A. Martin, *Science Gossip*, n. ser., vol. v., no. 52, p. 118 (189 other sections in this paper had been published before.

Water-level 190 feet down.

| | Thickness. |
|---|---|
| | Ft. |
| Pit... ... ... ... ... ... ... ... | — |
| Blue London Clay, with stone (septaria) from 48 to 54 feet down ... ... ... ... ... | 81 |
| [Reading Beds] Mottled clay ... ... ... ... | 42 |
| [Reading Beds] Green sand ... ... ... ... | 12 |
| Thanet Sand and pebbles [? flints] ... ... ... | 11 |
| Chalk and flints ... ... ... ... ... ... | 256 |
| Chalk ... ... ... ... ... ... ... | 79 |

The height above Ordnance Datum being 85 feet and the wat being 190 feet down, it is clear that by pumping year after y water-level in this part of London has been lowered to about below sea-level.

**Somerstown.** St. Pancras. Corner of Platt Street and Parchese Street, MIDLAND RAILWAY CO.

London Map 7 N.W. Height above Ordnance Datum 61 feet.

Communicated by Mr. W. TAYLOR. (In these brackets from Mr. W. N. BLAIR.)

(Permanent water-level while pumping 160 feet down.)

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| Soil (rubble) | ... ... ... ... ... ... | 4 | 0 | 4 | 0 |
| [Drift, 4 feet] | Yellow clay (4 feet) ... ... ... | 3 | 6 | 7 | 6 |
| | Gravel (and clay) ... ... ... | 0 | 6 | 8 | 0 |
| [London Clay, over 60 feet] | Yellow clay, with 3 inches of clay-stone at the base ... ... ... | 15 | 3 | 23 | 3 |
| | Blue clay, with dark clay-stone 1 to 1½ feet down ... ... ... | 25 | 11 | 49 | 2 |
| | Sandy clay ... ... ... ... | 4 | 0 | 53 | 2 |
| | Blue clay ... ... ... ... | 15 | 0 | 68 | 2 |
| [Reading Beds] | Mottled clay (marl) ... ... ... | 43 | 0 | 111 | 2 |
| | Loose sand (laminated sandy clay, 6 inches) ... ... ... ... | 0 | 7 | 111 | 9 |
| [? Thanet Sand] | Dead sand* ... ... ... ... | 27 | 11 | 139 | 8 |
| | Flints ... ... ... ... ... | 1 | 0 | 140 | 8 |
| Chalk ... | ... ... ... ... ... ... ... | 209 | 4 | 350 | 0 |

*Mr. Blair's account divides this bed as follows :—

Sandy clay ... ... 8
Dark sandy clay ... 8 } 27½ feet.
Grey sand ... ... 11½

The Drift must fill a small hollow in the London Clay.

It will be seen that even here, about a mile and a half north of Soho Square, the permanent water-level is nearly 100 feet below sea-level when pumping.

**Southampton Buildings.** BIRKBECK BANK, 1899.

London Map 7 S.W. Street level 68 feet above Ordnance Datum.

Made and communicated by Messrs. TILLEY.

Shaft to the Chalk.

Water-level 154½ feet down. Yield about 50 gallons a minute.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| To basement, below road-level ... ... ... | | — | 12 |
| [River Gravel] Ballast ... ... ... ... | | 15 | 27 |
| London Clay ... ... ... ... ... ... | | 85 | 112 |
| [Reading Beds, 43½ feet] | Coloured [mottled] clay ... ... | 15 | 127 |
| | Sand and water ... ... ... | 7 | 134 |
| | Coloured [mottled] sandy clay and pebbles ... ... ... ... | 15 | 149 |
| | Pebbles, sand and oyster-shells ... | 2 | 151¼ |
| | Sand and small pebbles ... ... | 4 | 155¼ |
| Fine [Thanet] sand and water ... ... ... | | 22¼ | 178 |

**Spitalfields.** Messrs. TRUMAN, HANBURY & Co., Coverley Fields, 1900.

London Map 7 S.E. Height above Ordnance Datum, about 45 feet.
Made and communicated by Messrs. LE GRAND and SUTCLIFF.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | | 3 | 3 |
| [River Drift, 23 feet] | Loamy clay ... ... ... ... | 3 | 6 |
| | Gravel ... ... ... ... ... | 20 | 26 |
| [London Clay, 80 feet] | Blue clay and clay-stone ... ... | 74 | 100 |
| | [Basement bed] Blue sandy clay ... | 5 | 105 |
| | [Basement bed] Pebbles ... ... | 1 | 106 |
| [Reading Beds, 57 feet] | Mottled sandy clay ... ... ... | 6 | 112 |
| | Mottled clay... ... ... ... | 25 | 137 |
| | Green sand ... ... ... ... | 3 | 140 |
| | Green sand and pebbles ... ... | 10 | 150 |
| | Grey sand and pebbles ... ... | 8 | 158 |
| | Clay, sand and pebbles ... ... | 5 | 163 |
| [Thanet Sand] | Grey sand ... ... ... ... | 37 | 200 |
| | Green flints ... ... ... ... | 1 | 201 |
| Chalk and flints ... ... ... ... ... | | 299 | 500 |

**Strand.** SAVOY HOTEL.

Height above Ordnance Datum 41 ft.; Water-level, 146 ft. 6 in. down.
Communicated by Mr. G. REEVES-SMITH, Secretary.
Well to Chalk, 9 in. bore below. Total pumped, 7,500 gallons per hour.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | | 7 | 7 |
| [River] Gravel ... ... ... ... ... ... | | 12 | 19 |
| London Clay ... ... ... ... ... ... | | 112 | 131 |
| [Woolwich and Reading Beds, 45 feet] | Red or plastic clay ... ... ... | 6 | 137 |
| | Light-coloured clay ... ... ... | 4 | 141 |
| | Grey sand ... ... ... ... | 3 | 144 |
| | Sandy loam ... ... ... ... | 2 | 146 |
| | Marly clay ... ... ... ... | 10 | 156 |
| | Dark clay ... ... ... ... | 1 | 157 |
| | Shelly clay ... ... ... ... | 1 | 158 |
| | Rock ... ... ... ... ... | 2 | 160 |
| | Black rock ... ... ... ... | 1 | 161 |
| | Dark brown clay ... ... ... | 3 | 164 |
| | Pebbles ... ... ... ... | 2 | 166 |
| | Dark grey sand ... ... ... | 3 | 169 |
| | Sand and pebbles ... ... ... | 1 | 170 |
| | Green sand ... ... ... ... | 6 | 176 |
| [Thanet Sand] | Thanet sand ... ... ... ... | 36½ | 212½ |
| | Green-coated flints ... ... ... | ½ | 213 |
| Chalk ... ... ... ... ... ... ... | | 192½ | 405½ |

**Uxbridge Road.** Close to Uxbridge Road Station. Messrs. Eastman & Sons. 1900.

London Map 6 S.E. Height above Ordnance Datum 25 ft.
Made and communicated by Messrs. A. C. Potter & Co.
Good supply of water.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Soil [? and Made Ground] | | 9½ | 9½ |
| [River Drift] Sand and ballast [gravel] | | 15 | 24½ |
| London Clay (blue) and clay-stones... | | 145 | 169½ |
| Reading Beds. | Mottled clays, grey, red, brown and yellow (6 beds) | 56½ | 226 |
| | Pebbles | 3 | 229 |
| Thanet Sand. | Sand | 24 | 253 |
| | Compact sand... | 3½ | 256½ |
| | Sandy clay | ½ | 257 |
| Chalk and flints... | | 194 | 451 |

**Wapping.** London Hydraulic Power Co., by side of River, close to Wapping Station, Thames Tunnel. 1892 ?

London Map 7 S.E. Height above Ordnance Datum 18½ feet.
Communicated by Messrs. Ellington & Woodall, with some particulars from the *Engineer*, vol. lxxv., p. 44 (1893).
Shaft throughout. Water-level about 40 feet down. Yield, 1,600 to 1,800 gallons an hour, pumping day and night.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground | | 15 | 15 |
| Alluvium, 12 ft. | Consolidated mud | 3 | 18 |
| | Peat | 5½ | 23½ |
| | Clay | 3½ | 27 |
| [River Drift] | Sand and ballast, to London Clay | 19 | 46 |

## West Drayton.

### 1. Britannia Brewery.

Made and communicated by Messrs. Baker.

| | | Thickness. | | Depth. | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| Made ground | | 2 | 0 | 2 | 0 |
| Mud | | 3 | 6 | 5 | 6 |
| Ballast [gravel] | | 7 | 0 | 12 | 6 |
| [London Clay] | Blue clay | 92 | 0 | 104 | 6 |
| | [Basement-bed] Pebbles | 2 | 0 | 106 | 6 |
| | [Basement-bed] Sandy clay 9 inches, and pyrites 3 inches | 1 | 0 | 107 | 6 |
| [Reading Beds, 73½ feet] | Coloured [mottled] clay | 31 | 6 | 139 | 0 |
| | Loamy sand | 6 | 4 | 145 | 4 |
| | Fine sand | 22 | 1 | 167 | 5 |
| | Stones [? pebbles] | 0 | 7 | 168 | 0 |
| | Hard dark clay | 12 | 0 | 180 | 0 |
| | Flints | 1 | 0 | 181 | 0 |
| Chalk | | 72 | 6 | 253 | 6 |

### 2. The Rotary Photographic Co.

Made and communicated (1901) by Messrs. Isler & Co.
Lined with 180 feet of tubes, 13¼ inches in diameter.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| [River Drift] Blue clay [? alluvial]... ... ... | 2 | 2 |
| [River Drift] Ballast [gravel] ... ... ... | 4 | 6 |
| [River Drift] ,, ,, and clay ... ... | 4 | 10 |
| Blue [London] clay ... ... ... ... ... | 83 | 93 |
| [Reading Beds, 76 feet] Mottled clay ... ... ... ... | 30 | 123 |
| [Reading Beds, 76 feet] Sandy clay and pebbles ... ... | 10 | 133 |
| [Reading Beds, 76 feet] Brown sand ... ... ... ... | 6 | 139 |
| [Reading Beds, 76 feet] Sandy clay ... ... ... ... | 3 | 142 |
| [Reading Beds, 76 feet] Live sand ... ... ... ... | 10 | 152 |
| [Reading Beds, 76 feet] Blue clay and stones... ... ... | 7 | 159 |
| [Reading Beds, 76 feet] Blue and black clay ... ... ... | 7 | 166 |
| [Reading Beds, 76 feet] Green sand and flints ... ... | 3 | 169 |
| Chalk and flints... ... ... ... ... ... | 131 | 300 |

## Westminster.

### 1. Millbank Street. Pumping Station of the London Hydraulic Power Station, just below Lambeth Bridge. Sump.

Communicated by Messrs. Ellington and Woodhall.
14½ feet above Ordnance Datum.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. (about) | Ft. (about) |
| Made ground ... ... ... ... ... about | 16½ | 16½ |
| [Alluvium] Peat ... ... ... ... ,, | 5½ | 21¾ |
| [River Drift] Sand ... ... ... ... ,, | 1½ | 23¼ |
| [River Drift] Ballast, to blue [London] clay ,, | 9½ | 32¾ |

### 2. Queen Anne's Mansions, Storeys Gate.

London Map 7 S.W." Height above Ordnance Datum, 13 feet.
Communicated by Messrs. Duke and Ockenden (1904), but not made by them.
Engine-room floor-level 13 feet below ground.
Shaft 209 feet, the rest bored.

| | Thickness. | Depth. |
|---|---|---|
| | Ft. | Ft. |
| [River Gravel] Ballast... ... ... ... ... | 37 | 37 |
| Blue [London] Clay ... ... ... ... ... | 101 | 138 |
| [? Blackheath and Woolwich Beds] Rocks, stones, &c. | 80 | 218 |
| [Thanet Sand] Thanet sands ... ... ... | 14 | 232 |
| [Thanet Sand] Flints ... ... ... ... | 3 | 235 |
| Chalk ... ... ... ... ... ... ... ... | 216 | 451 |

3. WESTMINSTER CHAMBERS. Northern end of Victoria Street.

London Map 7 S.W. Road-level 18 feet above Ordnance Datum. Well started at basement, below road.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground | ... ... ... ... ... ... | 5 | 5 |
| [Alluvium] | Peat ... ... ... ... ... | 1 | 6 |
| | Loamy sand ... ... ... ... | 3 | 9 |
| [River Drift] | Fine sand ... ... ... ... | 30 | 39 |
| | Gravel ... ... ... ... ... | 16 | 55 |
| [London Clay] | Loamy clay ... ... ... ... | 29 | 84 |
| | Clay ... ... ... ... ... | 71 | 155 |
| [Woolwich Reading and Beds, 70½ feet] | Mottled clay ... ... ... ... | 19 | 174 |
| | Grey sand ... ... ... ... | 18 | 192 |
| | Shells ... ... ... ... ... | 2 | 194 |
| | Mottled clay ... ... ... ... | 16 | 210 |
| | Coarse gravel... ... ... ... | 6 | 216 |
| | Coloured sand ... ... ... | 3 | 219 |
| | Green sand ... ... ... ... | 6½ | 225½ |
| [Thanet Sand] | Thanet sand (running) ... ... | 25½ | 251 |
| | Green-coated flints ... ... ... | 1 | 252 |
| Chalk ... | ... ... ... ... ... ... | 370 | 622 |

## Willesden.

1. MCVITIE & PRICE'S BISCUIT WORKS. Between the London and North Western Railway and the Canal, about 500 yards west of the Railway Bridge, Acton Lane.

London Map 6 N.W. Height above Ordnance Datum 100 feet.
Made in 1902 by the British-American Well Co.
Communicated by Messrs. MCVITIE & PRICE.
Sunk well to 10 feet, the rest an 8½ in. bore; lined to a depth of 12 feet in the Chalk, the rest of the bore left open.
Water-level 123 feet down.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay] | To base of yellow clay ... ... | — | 52 |
| | Blue-grey clay with hard streaks ... | 10 | 62 |
| | Blue-grey clay ... ... ... | 18 | 80 |
| | Brown clay ... ... ... ... | 46 | 126 |
| | Brown clay with boulders [? septaria] | 110 | 236 |
| | Clay ... ... ... ... ... | 4 | 240 |
| | Quicksand ... ... ... ... | 10 | 250 |
| | Clay and pebbles ... ... ... | 9 | 259 |
| [? Reading Beds, 61 feet] | Clayey sand ... ... ... ... | 20 | 279 |
| | Sandstone ... ... ... ... | 9 | 288 |
| | Flint (pebbles) ... ... ... | 2 | 290 |
| | Sand ... ... ... ... ... | 12 | 302 |
| | Flint (pebbles) ... ... ... | 3 | 305 |
| | Sand ... ... ... ... ... | 4 | 309 |
| | Flint (pebbles) ... ... ... | 2 | 311 |
| | Lime [?] ... ... ... ... | 2½ | 313½ |
| | Flints (pebbles) ... ... ... | 1½ | 315 |
| | Hard rock ... ... ... ... | 3 | 318 |
| | Flints ... ... ... ... ... | 2 | 320 |

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [? Upper Chalk, 406 feet] | Chalk and flints ... ... ... | 118 | 438 |
| | Chalk ... ... ... ... ... | 75 | 513 |
| | Chalk and sand ... ... ... | 11 | 524 |
| | Chalk and flint ... ... ... | 31 | 555 |
| | Hard chalk ... ... ... ... | 11 | 566 |
| | Lght-grey chalk ... ... ... | 85 | 651 |
| | Sand and chalk ... ... ... | 40 | 691 |
| | Chalk ... ... ... ... ... | 25 | 716 |
| | Chalk with small flints... ... ... | 10 | 726 |
| [? Middle Chalk, 111 feet] | Grey chalk marl ... ... ... | 24 | 750 |
| | Sand ... ... ... ... ... | 2 | 752 |
| | Chalk ... ... ... ... ... | 6 | 758 |
| | Micaceous streaks ... ... ... | 4 | 762 |
| | Grey chalk marl ... ... ... | 64 | 826 |
| | Hard chalk ... ... ... ... | 11 | 837 |

## 2. Metropolitan Electric Supply Co. 1900.

## In the angle between the Canal and Acton Lane, west of Willesden Junction.

London Map 6 N.W. Height above Ordnance Datum about 110 feet.
Made and communicated by Messrs. Isler & Co.

Pit 12 feet deep, the rest bored. Lined with 345 feet of tubes of 11 inches diameter, from 7 feet down. Water-level 136 feet down (September when 930 feet deep). Yield from the Chalk from 1,500 to 2,000 gallons an hour, at the depth of 900 feet.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay] | Brown clay ... ... ... ... | 59 | 59 |
| | Blue clay and brown clay, with 15 inches of clay-stone at the bottom | 144 | 203 |
| | Brown clay, with clay-stone at 223½ to 224 ... ... ... ... | 63 | 266 |
| [Reading Beds, 74 feet] | Mottled clay ... ... ... ... | 40 | 306 |
| | Loose black [flint] pebbles ... ... | ½ | 306½ |
| | Brown sand ... ... ... ... | 1½ | 308 |
| | Sand, stone and pebbles ... ... | 23½ | 331½ |
| | Green sand ... ... ... ... | 8½ | 340 |
| [Upper Chalk] | Chalk and flints (160, 70 and 85 feet) | 315 | 655 |
| [Middle Chalk] | Very hard chalk and chalk (22 and 96 feet)... ... ... ... ... ... | 118 | 773 |
| [Lower Chalk] | Grey chalk (67, 40 and 18 feet) ... | 125 | 898 |
| | Grey chalk, darker ... ... ... | 8 | 906 |
| | Grey chalk, darker ... ... ... | 14 | 920 |
| | Gault, hard, with hard layers ... | 10 | 930 |

### 3. Neasden. Metropolitan Railway Works, 1902.

London Map 2 S.W. Height above Ordnance Datum about 105 feet.
Made and communicated by Messrs. Tilley.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| Made ground ... ... ... ... ... ... | | 3 | 3 |
| Ballast and water ... ... ... ... ... | | 5 | 8 |
| London Clay. ... ... ... ... ... ... | | 29 | 37 |
| [Reading Beds] | Coloured [mottled] clay ... ... | 41 | 78 |
| | Black sand and pebbles (as hard as concrete) ... ... ... ... | 17 | 95 |
| | Green-coated flints, to Chalk ... | ½ | 95½ |

The small amount of London Clay here is unexpected.

### 4. Park Royal. South-east of Twyford Abbey, in the grounds formerly belonging to the Royal Agricultural Society, 1904.

London Map 6 N.W. Height above Ordnance Datum about 105 feet.
Made and communicated by Messrs. Tilley.

| | | Thickness. | Depth. |
|---|---|---|---|
| | | Ft. | Ft. |
| [London Clay] | Yellow clay ... ... ... ... | 18 | 18 |
| | London clay ... ... ... ... | 209½ | 227½ |
| | Dark sandy clay ... ... ... | 35½ | 263 |
| [Reading Beds, 67 feet] | Coloured [mottled] clays ... ... | 31½ | 294½ |
| | Hard white sand and clay ... ... | 2 | 296½ |
| | Yellow blowing sand and water ... | 3½ | 300 |
| | Coloured [mottled] clays ... ... | 19 | 319 |
| | Black [flint] pebbles ... ... ... | 5 | 324 |
| | Green clay and pebbles ... ... | 6 | 330 |
| [? Thanet Sand] | Hard grey sand ... ... ... | 26 | 356 |
| | Softer grey sand ... ... ... | 3½ | 359½ |
| | Flints... ... ... ... ... | ½ | 360 |
| Chalk ... ... ... ... ... ... ... | | 240 | 600 |

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MEMOIRS OF THE GEOLOGICAL SURVEY.

# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

OF

# GREAT BRITAIN

AND THE

# MUSEUM OF PRACTICAL GEOLOGY

FOR

# 1907.

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# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

AND

# MUSEUM

FOR 1907.

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## *INTRODUCTION.*

By J. J. H. Teall, M.A., D.Sc., F.R.S., Director.

In England and Wales work has been continued in the West of England, Pembrokeshire, and the Midlands. In the West of England the surveying of the Lizard area has been nearly completed, while work has proceeded in the north in the Camelford, Tavistock, and Boscastle districts. In Pembrokeshire progress has been made with the survey of the South Wales coalfield and of the adjacent areas, so far as they are included within the one-inch sheets in which Coal-measures occur. In the Midlands the survey has been continued in the Matlock, Mansfield, and Ollerton districts.

The original survey of Scotland has been continued between Glencoe and Ben Nevis, in the higher portions of the basins of the Findhorn, the Dulnan and the Nairn, in the islands of Mull and Colonsay, and in Caithness. The revision of the Carboniferous areas in the Midland Valley has also been proceeded with.

Two small areas, somewhat doubtfully referred to the Lewisian Gneiss, have been met with during the year; one in the small island of Soa to the south of Iona, and the other in Colonsay.

In the mountainous region between Glen Nevis and Glen Coe, the principal rock groups, which are for the most part sharply defined and easily traceable, consist of quartzites, mica schists and granulites of Moine type. Complicated folds of exceptional clearness have been recognised, and when the whole district has been mapped it will be possible to form some definite idea as to the nature of the stresses which have determined the structure of this interesting region.

In the basins of the Findhorn, Dulnan, Spey, and Nairn, the phenomena met with are similar to those already referred to in previous Summaries. The rocks consist of metamor-

phosed sediments and igneous intrusions, mostly of a granitic character. Granitic material not only forms large irregularly shaped masses, bosses, veins and dykes, which can be represented on a geological map, but also minute *lit-par-lit* injections, which may become so numerous as to make it difficult to say whether the compound rock should be regarded as of igneous or sedimentary origin.

In addition to the granite-intrusions there occur also—though on a much smaller scale—certain basic sills and dykes which have been converted by dynamic action into hornblendic and chloritic schists.

Highland metamorphic rocks have also been surveyed in Caithness. Granulites of the Moine type and quartzites have here been invaded by granites of two ages, those of the earlier period being now in the condition of augen-gneiss. The later granites cover large areas and, in the case of the Strath Halladale mass, have impregnated the schists for long distances from the principal margin, so as to produce a mixed complex on a regional scale.

Small areas of Highland schists have also been mapped in the islands of Mull and Lismore.

) Lizard ks.

The re-survey of the Lizard district of Cornwall has been continued on the lines referred to in last year's SUMMARY. Special attention has been paid to the relative ages of the different kinds of igneous rocks and of the foliated structures which so many of them possess. The outline of a theory to account for the complicated phenomena of the district is given in the following pages.

e John- n Ridge.

The rocks of the Johnston ridge south of Haverfordwest form an igneous complex of variable character, in which a dioritic rock predominates. The complex is traversed by numerous basic dykes which do not cut the adjacent sediments. It is bounded by faults, that on the north side being apparently of low hade and due to a thrust from the south. The mass may be of pre-Cambrian age and is therefore referred to here.

rridonian.

A group of more or less altered sediments occurring in the island of Colonsay has been provisionally referred to the Torridonian formation. Apart from the question of the age of the sediments, the rocks of the island are interesting as furnishing evidence of having been subjected to two distinct sets of compressive stresses separated by a period of igneous intrusion. Sills or dykes of an igneous rock referred to the lamprophyres were intruded after the first set of movements had taken place, and then subsequently foliated by the second set.

wer læozoic.

In South Wales further progress has been made with the mapping of the Cambrian, Ordovician and Silurian rocks which lie within the one-inch sheets containing portions of the coalfield. On the north side of the Pembrokeshire coalfield the various subdivisions to which reference has been made in previous Summaries have been traced still further towards

the west, but no new type of structure has been met with. On the south side the inliers, which are represented as Upper Silurian on the Old Series one-inch map, between the two bays of Freshwater East and Freshwater West, have been mapped in detail with the interesting result that cores of rock of Arenig age have been detected in the centres of the anticlinal folds.

Devonian

The mapping of Devonian rocks both on the east and on the west sides of the granite-mass of Bodmin Moor has been continued. The tracing of the boundary between the Upper and Middle Devonian in the district to the north and west of the Camel has proved a task of considerable difficulty owing to the absence at the junction of any well characterised lithological band, and the scarcity of fossils. A line separating the purple and green from the grey rocks has been shown to be unsatisfactory as a stratigraphical horizon. Greenstones possessing the now well-known pillow-structure have been shown to occur in the Upper Devonian.

The granite-mass of Bodmin Moor lies wholly in the Devonian area and produces a well marked aureole of contact-alteration. The river Camel, in its course from north to south, touches the western margin of the granite-mass and thus cuts twice through the metamorphic aureole furnishing admirable exposures of the contact rocks. Some particulars as to these rocks are recorded in the following pages but fuller details are reserved for the memoir.

One interesting and somewhat unexpected result of the mapping of the boundary of the granite has been the discovery that not unfrequently it is a fault.

Special attention has been paid to the occurrence of wolfram in the Altarnun district. When the old mines in this district were worked for tin the occurrence of wolfram was a serious drawback but now it adds greatly to their value and some of them are being opened up.

The Old Red Sandstone facies of the Devonian has been met with during the year in Pembrokeshire and Caithness.

Carbon-
ifer

Carboniferous rocks have been surveyed in Cornwall, Pembrokeshire, Derbyshire, Nottinghamshire, and the Midland Valley of Scotland.

The extension of the Culm-measures of Devon and Cornwall far to the south of the area in which they are recorded as occurring on the earlier one-inch maps is well known. Thus, in the Plymouth Sheet (348), published during the year under review, a large tract is represented in the neighbourhood of St. Mellion. The extension of this outlier into the area between the granite masses of Dartmoor on the east and Bodmin Moor on the west has now been traced. Other outliers have been surveyed in the same area and the main boundary line between Culm-measures and Devonian has in some places been considerably modified. In view of the fact that the two groups are known to have been interfolded, these results are in no way surprising, and it may be predicted wit[illegible]

some degree of confidence that inliers of Devonian rocks will be found in the Culm-measure area to the north.

Passing now to the other side of the Bristol Channel we have to note that further progress has been made with the survey of the Pembrokeshire coalfield. In last year's SUMMARY attention was directed to the fact that the lower beds of the Carboniferous sequence die out as they are traced westward. The work done during 1907 has brought to light further illustrations of the same fact; thus the Millstone Grit has been found to overlap the Carboniferous limestone and the upper portion of the Millstone Grit to overlap the lower as the beds have been traced westward.

The Coal-measures have now been followed as far as the Daucleddau. The measures have been thrown into a series of plications ranging west-north-west, and certain portions have been repeated by numerous overthrust faults following the same general direction. That this is the general structure is perfectly clear but the details cannot be fully made out owing partly to their complexity and partly to the absence of exposures.

In Derbyshire that portion of the Carboniferous Limestone which comes within the area represented by Sheet 112 has been carefully studied with reference to the zonal work of Dr. Vaughan. Three subdivisions of the *Dibunophyllum*-zone have been traced in the Matlock district. The detailed mapping on the six-inch scale has thrown much additional light on the structure of this district and the general results of this work are recorded in a sketch map in black and white. Further progress has been made with the mapping of the exposed part of the Derbyshire and Nottinghamshire coalfield between Alfreton and Tibshelf, but the most important work, so far as the Coal-measures are concerned, is recorded in an Appendix on the Extension of the Yorkshire and Nottinghamshire Coalfield. In this Appendix an account is given of the chief practical results obtained from the examination of borings and sinkings situated between Gedling and Selby. Attention is drawn to the varying thickness of cover formed by the Trias and Permian formations and to the location of those fossiliferous zones in the Carboniferous series, which, as stated in previous Summaries of Progress, readily identify the positions of the more important seams of coal. It is now certain that a band of considerable thickness, possessing distinctive lithological characters, and containing a marine fauna, peculiar to this bed, everywhere occupies a definite position above the Top Hard (Barnsley) coal and will therefore afford the miner an index of the depth to this important seam over the concealed coalfield.

In Scotland, now that the revision of the Glasgow area has been finished, the re-survey has been extended eastwards so as to join up ultimately with that already completed in the Edinburgh district. In view of the importance of the fire-clay industry, special attention has been paid to the distri-

bution of the Millstone Grit, in which the more important fire-clays occur. The information now available for tracing this distribution is much more complete than that accessible to the earlier surveyors and it is therefore not surprising to find that modifications, in some cases of considerable local importance, have to be made in the earlier maps.

In revising the Coal-measure areas much information obtained from bores and sinkings, has been acquired through the courtesy of Coal-owners and others; but the full discussion of the results must be allowed to stand over for the present. One of the most interesting results of the year's work has been the recognition of a characteristic Upper Coal-measure (Radstockian) flora in the barren red-measures of Ayrshire.

Permia and Tr

A small area of Permian rocks has been surveyed in the neighbourhood of Mansfield (Nottinghamshire). The Red Marls overlying the Magnesian Limestone which are about twenty feet thick at Nottingham retain this thickness as far as Mansfield, where they rapidly thin out so that the Bunter comes to rest directly on the Magnesian Limestone.

Triassic rocks occupy a large part of the Ollerton Sheet (113), in which work is going on. The main subdivisions now being mapped are the same as those recognised during the earlier survey on the one-inch scale; but the use of six-inch maps of course enables a much greater degree of accuracy to be attained. A large tract of Bunter Pebble Beds in and around Sherwood Forest has been surveyed. The formation as a whole is readily pervious to water but a few thin partings of marl have been observed, and these probably account for the small springs which ooze out in places in the sandy country. Springs are also not infrequent at the base of the Keuper. An impersistent conglomerate has been observed at this horizon and there are other indications of a slight unconformity.

The main interest in the mapping of the dissected Keuper plateau lies in tracing the thin sandstones or "skerries." These are found to be persistent over a wide area and, in the absence of drift, can be laid down with great precision by means of the slight features to which they give rise. The mapping of these skerries has proved that the rocks are rolling gently with the axes of the folds at right angles to the general strike of the beds. Faults are conspicuous by their absence. The comparatively undisturbed character of the Triassic rocks is probably a good omen for the future development of the concealed portion of the coalfield.

Rhætic Jurassi

A small area of Rhætic and Lias north of Newark has been mapped but the outcrops are mostly obscured by Glacial Gravels.

Liassic rocks have also been met with in the south-eastern corner of the Island of Mull, where they have been thrown into a sharp anticlinal fold together with the Tertiary basalts.

A new direct route to Birmingham is in course of construction by the Great Western Railway Co., and a fair

complete series of sections from the Ampthill Clay (Corallian) to the Lower Lias has been examined between Ashendon in Buckinghamshire, through Bicester to Aynho near Banbury in Oxfordshire.

The cuttings on a new branch line from near Limpley Stoke in Wiltshire to Camerton near Radstock in Somerset, have also been examined. They include sections from the Inferior Oolite to the Keuper Sandstones and Marls.

The main object in examining these sections has been to record the outcrops and boundary lines of the several formations; also the faults and other data of importance that may be utilised when the six-inch geological survey of those parts of the country is carried out. In the meantime, brief notes of the results of this work, which was in part carried out during the present year, are published in the form of Appendices to the SUMMARY.

ocene The superficial deposits have been surveyed in all areas in which work is going on, but owing to their local character and great diversity the results cannot well be summarised; only one or two points will therefore be referred to.

Glacial deposits are conspicuous by their absence in Cornwall, but in their place we have the so-called "head" or accumulations of local detritus on slopes. A deposit of this character which is both of scientific and economic importance has been met with on the granite-mass of Bodmin Moor. It is found between the 750 and 1,000 ft. contours, which correspond approximately to two well marked plateaux, and where it occurs in a region containing veins of cassiterite and wolfram is sometimes found to yield these ores in sufficient quantity to pay for working.

In that portion of Pembrokeshire in which work has been carried on, boulder clay is scarce but drift gravels are fairly abundant between the contours of 100 and 200 ft. The valleys are practically free from drift. Boulders of considerable size are fairly common and one type—a hornblende-porphyrite—has not yet been traced to its source.

In Nottinghamshire the comparatively driftless area to which reference has been made in previous Summaries has been found to extend further northwards into the region surveyed during 1907, but in a few localities within the area undoubted glacial deposits, including far travelled erratics, have been observed. It may therefore be assumed that glacial conditions prevailed over the area and that the scarcity of drift deposits must be accounted for either by the absence of conditions favourable to deposition or to the subsequent removal of deposits, or as is most probable, to both causes combined.

The work carried on in Scotland in the higher portions of the basins of the Dulnan and the Findhorn has added much to our knowledge of the glacial history of this interesting region. The records left in the shape of boulder clay, morainic drift, gravels, lake deposits, erratics, striæ, marginal and overflow channels are exceptionally well preserved and

suffice to enable a fairly clear idea of the physical history of the district during the later stages of the glacial period to be obtained. Some details are given in the following pages, and it is evident that when the survey is complete it will be desirable to piece together the evidence obtained from the whole area, irrespective of the limits of the one-inch sheets, and so furnish a more or less connected account of the sequence of events from the time of maximum glaciation to the present day.

In conclusion attention may be directed to two appendices of considerable historical interest.

There has hitherto been considerable doubt about the dates of publication of the earlier one-inch maps of the south-western counties in England, but Mr. Woodward has been enabled by a study of the successive indexes of colours issued by the Geological Survey, and from particulars given in the Proceedings of the Geological Society, to affix in some cases the actual, and in other the probable, dates of publication of the early maps of De la Beche, of revised editions of some of them, and of the dates of successive changes in the colouring.

A useful Appendix has also been contributed by Mr. Crook, who has given a record of the MS. maps and sections preserved in the Library of the Geological Survey and Museum, excepting only a full list of the official MS. six-inch maps.

# I.—ENGLAND AND WALES.

## I.—FIELD-WORK.

odward.

The ground to be surveyed was arranged in three areas as follows:—

1. Midland district under Mr. G. W. Lamplugh.
2. Southern district under Mr. C. Reid.
3. South Wales district under Dr. A. Strahan.

In addition to the ordinary field-work Mr. George Barrow examined the cuttings on the new Great Western Railway between Ashendon, Bicester, and Aynho near Banbury. He likewise investigated the cuttings on the new railway in course of construction between Enfield and Little Berkhampstead, and made some further notes on the strata penetrated in the Rotherhithe road-tunnel.

Dr. Gibson studied materials and collected information from important borings and sinkings for coal at Wentbridge, Brodsworth, Bentley, Thorne, Maltby, Owthorpe and Chorley, in areas outside the limits of those at present in course of survey.

Mr. MacAlister, Mining Geologist, examined the old mine plans of Devonshire that are preserved in the Home Office, and marked the lodes on the six-inch maps.

### 1.—Midland District—Derbyshire and Nottinghamshire.

Mr. G. W. Lamplugh, F.R.S., District Geologist.
Mr. W. Gibson, D.Sc.
Mr. C. B. Wedd, B.A.
Mr. R. L. Sherlock, B.Sc.
Mr. B. Smith, M.A.
} Geologists.

The field-work of the year lay within the two adjacent Sheets, 112 (Chesterfield) and 113 (Ollerton). In the former map Mr. Wedd carried the survey of the Lower Carboniferous rocks northward from Matlock, and Dr. Gibson surveyed a portion of the coalfield between Alfreton and Tibshelf. Mr. Sherlock, working from Mansfield, surveyed a stretch of Permian and Trias in the south-eastern part of Sheet 112 and the south-western part of Sheet 113; Mr. Smith carried the work eastward across the remainder of the Triassic outcrop up to the south-eastern margin of the latter sheet; and Mr. Lamplugh mapped a strip of country south and north of Ollerton, up to the northern edge of this sheet. Dr. Gibson also continued his examination of several deep sinkings and borings for coal in other districts adjacent to the North Midland Coalfields.

## CARBONIFEROUS LIMESTONE SERIES.

The sequence and structure of the Carboniferous rocks above the base of the Millstone Grit in the Matlock district were outlined in the SUMMARY OF PROGRESS for 1905. The survey of the underlying Carboniferous Limestone Series with its interbedded volcanic rocks, so far as these fall within Sheet 112, has now been completed and can be similarly discussed. Mr. W

Adopting the method of zonal classification based upon the fossil corals and brachiopods of the limestone, as first applied by Dr. Vaughan and his colleagues in the south-west of England, we may summarize the sequence and faunal divisions of the exposed limestone as follows in downward succession:—

### ZONE OF DIBUNOPHYLLUM (D).

#### *Subzone of Cyathaxonia* (D3).

Thin-bedded blue limestones with chert and thin shaly partings: these contain a characteristic fauna, including *Cyathaxonia rushiana* (Vaughan), and *Zaphrentis* aff. *enniskilleni* (E. and H.). *Lithostrotion junceum* (Flem.) occurs, and *Productus giganteus* (Mart.) and *P. concinnus* (Sow.) are abundant. It is doubtful whether *Dibunophyllum* is present, except perhaps in the lowest beds. The thickness of the *Cyathaxonia* beds is about 35 ft., exclusive of the part which falls within the overlying shale series.

#### *Subzone of Lonsdalia floriformis* (D2).

Limestones, partly thin-bedded, cherty and blue like the above, partly more massive, crinoidal, chertless and of a paler blue passing down into fawn or cream colour. The group is characterized by *Lonsdalia floriformis* (Flem.), more or less highly specialized forms of *Dibunophyllum*, and an important group of clisiophyllid corals including *Histiophyllum*, etc. *Lithostrotion martini* (E. and H.), *L. irregulare* (Phill.) or closely allied forms and *L. junceum* are very abundant, while *Diphyphyllum* occurs frequently. *Lonsdalia duplicata* (Mart.) or a variant is very characteristic of the highest beds of the group, and *Cyathophyllum regium* (Phill.) is frequent in the upper half but widely distributed throughout. *Productus giganteus* and variants of *P. semireticulatus* (Mart.) are found in great numbers. *Spirifer planicosta* (McCoy), and *S. bisulcatus* (Sow.) range throughout, while *Schizophoria resupinata* (Mart.), often of large size, is met with in the upper beds. Maximum thickness about 115 ft.

The upper lava (toadstone), where present, ranges up to a thickness of 80 ft.

More or less massive limestone, usually pale or whitish. The fauna is similar to that of the D2 beds above the upper lava, but *Lonsdalia duplicata* is rare if it occurs

at all, and *Schizophoria resupinata* is perhaps absent. On the other hand *Dibunophyllum*, *Histiophyllum*, and other clisiophyllids are very abundant, especially in a bed near the bottom, where *Campophyllum* also occurs. *Productus giganteus*, *P. hemisphaericus* (J. Sow.), and semi-reticulate species of the genus are still abundant, and *Spirifer planicosta* is plentiful. The thickness probably varies up to 150 ft.* The tuff of the Grange Mill district probably lies at or within the base of these beds.

The lower lava (toadstone): maximum thickness about 100 ft.

*Subzone of Dibunophyllum θ* (D1).

Massive pale and whitish limestones (Hoptonwood Stone) for the most part of more homogeneous texture than the higher beds, contain occasional thin clay-bands. The rock is usually much less fossiliferous than the beds of D2 and D3. Corals have been found at few horizons. *Dibunophyllum* of a rather simple type occurs sparingly, and chiefly in the higher part. *Syringopora* and a small *Cyathophyllum* are abundant at one or two levels. *Productus giganteus* is widely distributed but much less common, while *P. hemisphaericus* occurs in profusion at some levels. Species of *Bellerophon* and other gasteropods are rather frequent. The thickness probably exceeds 200 ft.

Very compact and fine-grained pale limestones (Holystone) of porcellaneous aspect, with occasional oolitic bands and thin granular beds. Foraminifera are very abundant; such other fossils as occur show the same facies as those of the overlying beds. A thickness of about 100 ft. is seen.

The characters of the D1 fauna in this district are mainly negative: *Lonsdalia floriformis* and other essential forms of the D2 fauna appear to be absent, and both corals and brachiopods are less numerous. Such species as are present have the general aspect of a D1 fauna, while no forms especially characteristic of a lower zone have been noticed. Mr. Sibly finds a much greater thickness of beds below D2 to be devoid of all traces of a lower fauna in other parts of Derbyshire.

The presence of chert of a tabular or nodular habit, together with a rather deep blue colour of the limestone, is always characteristic of the highest beds of the formation. Except that for a short distance on the north side of Matlock this type of limestone is not developed below the base of D3, its thickness elsewhere throughout the neighbourhood of Matlock and at Crich is fairly constant at about 60 ft., its base being

* This appears to be the thickness at High Tor, the only place where a direct estimate of the beds above the lower lava can be obtained, but Mr. Arnold-Bemrose regards it as an over-estimate, basing his view on barometric measurements in other parts of the district ("The Toadstones of Derbyshire; their Field-relations and Petrography." *Quart. Journ. Geol. Soc.*, vol. lxiii., 1907, p. 41).

thus somewhere about 25 ft. below that of the D3 fauna. But south-west of Middleton the blue cherty type of rock encroaches downward and pervades the strata of D2 down to a horizon only about 50 ft. above the lower lava. A thin development of chert, usually of a pale colour and in pale limestone, is met with locally at Matlock Bath about 35 ft. above the upper lava, and similarly 200 ft. or more below the lower lava under the north side of Middleton Moor. The limestone for a few feet above both lavas is usually of a deep blue colour.

### MILLSTONE GRIT SERIES.

The same sequence of the Millstone Grits as described in previous SUMMARIES OF PROGRESS continues northward, in which direction the Kinderscout Grit becomes finer-grained in part, and is frequently split by alternations of sandy shale. The Belper-Grit of Sheet 125 proves to be continuous with the Chatsworth Grit, as anticipated; but in the neighbourhood of Sydnope and Chatsworth it becomes partly coarser-grained and pebbly. A marine bed with *Glyphioceras bilingue* (Salt.) and *Posidoniella* was noted a short distance below this grit in the northern part of Hall Dale, and another bed of goniatites and *Pterinopecten* occurs just above the succeeding grit on Beeley Moor.

### *Main Structural Features of the Matlock District.*

The structure of the south-eastern termination of the Derbyshire limestone area is shown on the accompanying sketch-map (Fig. 1). The limestone enters this district as a broad anticlinal elevation trending somewhat south of east, with a corresponding synclinal depression on its north side occupied by the overlying shales and Millstone Grits. This compound anticline embraces two principal saddles separated by a narrow faulted syncline. The northern saddle is a relatively high and narrow elevation with a well-defined axis running roughly from west to east through Blakelow Hill (on which beds below the lower lava reach an altitude of 1,200 ft.), through the dolerite sill of Bonsall and through High Tor. It dies out along the northern edge of Riber Hill in the Millstone Grits. It is accompanied by one or two shallow minor folds on its northern flank which has on the whole a rather high dip.

The southern anticline, which has no axis sufficiently definite to be indicated on the sketch-map, forms a broader but rather lower feature in which strata above the lower lava attain a maximum height of 1,170 ft. on Middleton Moor. Though its essentially anticlinal structure is shown by the uplift of the lowest beds of the sequence in the middle, and by its marginal fringe of the upper cherty beds, it includes several smaller wrinkles not easy to trace in detail.

FIG. 1.—*Geological Sketch-map of Matlock.* (Drifts not shown.)
By C. B. WEDD.

The relatively narrow syncline between these two principal anticlines is occupied by a fault of some importance to the interpretation of the stratigraphy. This fracture, which may be styled the Bonsall Fault, enters the limestone in a west-north-west direction at Cromford market-place. The main fault runs along the northern brow of Bonsall Hollow to Bonsall Church. In this part of its course it throws down the chert beds of the higher part of D2 on the north successively against the upper and lower lavas and underlying beds in the neighbourhood of the church, where its displacement must have reached a maximum of something like 400 ft. Here it bends more to the west, and there is reason to believe that it forms the southern boundary of the Bonsall Sill. It may be remarked incidentally that whatever the age of this sill, it is older than the system of west-north-westerly faulting, for in one place it is sheared and veined in that direction.

The exact position of the Bonsall Fault on the southern side of the sill is difficult to define, but it clearly continues along the synclinal valley further west and throws down strata above the lower lava on the south against the anticlinal beds of Blakelow Hill, which are below that lava.

This fault has the same general direction and throw as the Southern Crich Fault, in Sheet 125, to which it is parallel and evidently complementary.

The maximum displacement at Bonsall is influenced by a sharp monoclinal accentuation of the southern limb of the northern anticline. This monocline produces the steep downward bend of the limestone at the south end of Matlock Dale and along the Heights of Abraham, but terminates at the fault. It is accompanied on the south by a syncline increasing eastward and continuing as the trough in the Kinderscout Grit of Riber Hill, and further south by the gentle anticline of Matlock Bath (see sketch-map) trending south of east.

In accordance with the structure described above, it will be seen that the outcrop of the cherty limestones of D3 and the top of D2 is confined to the outer edge of the limestone area, except where these beds are let down into the interior by the Bonsall Fault, and in the neighbourhood of Wirksworth where denudation has exposed lower strata along the faulted margin of the limestone; that the whole sequence from these chert-beds downward rises again in a westerly or south-westerly direction from the Bonsall Fault; and that the beds of the subzone D1 are brought to the surface in three tracts, viz.: Blakelow Hill and the west flank of Masson Hill (where they are much silicified) on the north side of the fault, and in the larger tract of Hopton and the Via Gellia Valley south of it.

Another fault, but with northerly downthrow, runs parallel to the Bonsall Fault from the Derwent Valley, at Willersley, north of Cromford. It does not extend far, but, between the two fault-planes which if produced upward would intersect, the sharp ridge of Harp Edge stands up as a "horst" of th[illegible]

pale limestone above the upper lava. On either side the higher cherty limestones dip inwards at a lower level.

The Bonsall Fault has an interesting bearing on the possible connexion of the Bonsall and Ible Sills. The Grange Mill tuff can be traced southward into close relationship with the upper edge of the Ible Sill, and there is further reason to believe that its horizon lies close to, and perhaps a little above, that of the lower lava. Moreover, the limestone overlying this tuff contains a characteristic D2 fauna, such as has not been found below the lower lava. Hence it seems that the Ible Sill traverses much the same range of limestone as the Bonsall Sill does, *i.e.*, they both transgress from beds considerably below the lower lava approximately up to the horizon of that lava. Mr. Arnold-Bemrose has shown that the two sills are similar in composition;* and the Ible Sill passes north-eastward beneath the surface of the limestone. Hence it may be suggested with some reason that the Ible and Bonsall Sills are parts of the same intrusive sheet, the Ible portion being thrown down by the Bonsall Fault.

In addition to the three agglomerates or coarse tuffs recorded by Mr. Arnold-Bemrose around the Bonsall Sill, a fourth has recently been noted in the material of a shaft south of Uppertown, where it seems not to reach the surface. It lies on the downthrow side of the Bonsall Fault.

An interesting structure was examined in the spur of limestone at Bolehill. The main fault at Middleton, known as the Gulf Fault, and the Rantor Fault, $\frac{1}{4}$ mile further eastward, are two parallel north-westerly fractures letting down "the Gulf," a long trough of shale, into the limestone. These two faults belong to a series of parallel dislocations with alternate north-easterly and south-westerly downthrows. A fault of low hade, which has dragged down the Limestone Shales against the pale limestones below the cherty beds, intersects these north-westerly fractures. In a newly-opened quarry one of the latter faults is seen to throw down on the east the black shales of the Limestone Shales, resting with little disturbance but with a faulted junction of low inclination upon the pale massive limestones, against alternations of dark limestone and shale on the west, containing a D3 fauna and resting with a similar junction also upon pale massive limestones. In the low-hading east and west fault, where the black shales abut upon the massive limestone, both show slickensiding, and the uppermost bed of the massive limestone has pinched in and overridden wisps of the shale in the downward drag.

The long sinuous anticline described in the SUMMARY OF PROGRESS for 1905 as ranging from Belper through Crich and Ashover, dies out north of the last-named village. This saddle, swerving round the end of the compound anticlinal uplift of the limestone spur that enters the district (see sketch map, p. 12), and conforming closely to its outline, thus comes

* "The Toadstones of Derbyshire; their Field-relations and Petrography," *Quart. Journ. Geol. Soc.*, vol. lxiii., p. 241 (1907).

to an end in both directions as soon as it passes beyond the influence of that uplift. It is in fact a transverse wrinkle produced simultaneously around the end of the larger fold, with a complementary transverse syncline intervening. Two opposing forces, acting in general northerly and southerly directions, so as to raise the east-and-west anticline of this spur of the Derbyshire Limestone, but inducing a certain amount of torsion by not acting in the same line, would naturally produce the main features of the structure here described.

## COAL MEASURES.

The area surveyed during the year includes a tract of Coal Measures situated between the outcrop of the Magnesian Limestone from Hucknall-under-Huthwaite to Kirkby-in-Ashfield on the east, and the outcrop of the sandstone above the Tupton Coal to the west of Morton and Alfreton. Dr. Gibso

With the exception of the shallow fault-bounded syncline of Alfreton, which introduces a small area of measures above the Top Hard Coal, the strata are gently inclined eastward and are but little disturbed or faulted.

In ascending sequence, the chief seams being worked are the Silkstone, Low Main (Furnace or Tupton), Deep Hard, Deep Soft, and Dunsil. The Top Hard Coal crops out around Tibshelf, where good sections of the associated measures are to be seen near the Great Central Station, and around Blackwell, but the seam has been practically exhausted. The Waterloo Coal where exposed in the floor of a shallow clay-pit near the Alfreton Colliery gives the following section:—Coal 1 ft. 3 in., cannel 10 in., coal 1 ft. 3 in. A seam, 3 ft. thick, visible in a clay-pit at Alma Terrace, Alfreton, is locally considered to be the Combe Coal. If this identification is correct the seam lies 57 ft. above the Top Hard Coal.

With the exception of the features formed by the sandstones above the Tupton Coal, Deep Soft Coal and Deep Hard Coal, and by those a short distance over the Top Hard Coal, the area presents little structural relief. The sandstones above the Top Hard Coal form the high ground round Tibshelf, Blackwell, Alfreton and South Normanton; but are scantily exposed, as owing to their shaly character they are not quarried.

The roof-shale of the Tupton Coal is prolific in fossil lamellibranchiata, including *Carbonicola robusta*, *C. acuta* and *C. turgida*, along with numerous fragmentary fish-remains.

A coal-seam, 2 ft. 6 in. thick, crops out in a small overgrown stream flowing south-west through Bloomer Wood, about 1 mile N.N.W. of Kirkby and Pinxton Station. It lies at 450-500 ft. above the Top Hard Coal, or at a much higher horizon than a seam known as the Main or Furnace Coal of the Hucknall Torkard Colliery, or than the High Hazles Coal of Gedling Colliery.

## PERMIAN.

### *Magnesian Limestone.*

Gibson. The Permian rocks form a low escarpment from Kirkby-in-Ashfield to a little south of Teversall where they loop into the Meden Valley.

Though the lower beds are exposed in several places in this part of the escarpment, the breccia-band that occurs at the base farther southward is nowhere visible and possibly does not exist. The lowest beds consist of sandy shales and clays containing numerous carbonised and indeterminable fragments of plants. Above these are some thin limestones, a few feet in united thickness, containing numerous casts of *Schizodus*. These are overlain by the more thickly-bedded Magnesian Limestone which extends in a broad outcrop eastward.

Sherlock. The flaggy type of limestone composed of rhombs of dolomite cemented by calcite, characteristic of the Nottingham district, extends without interruption to beyond Sutton-in-Ashfield. Between Sutton and Mansfield it becomes sandy in the upper part, and south of Mansfield has become a whitish dolomitic sandstone, one of the well-known building-stones of the district. In the Rock Valley on the eastern border of Mansfield there is a rock of similar composition but of a red colour. This rock passes up into a yellow dolomite which forms the top of the Magnesian Limestone.

The quarries at Mansfield Woodhouse, two miles N. of Mansfield, are in a compact dolomite. This variety of dolomite occurs in steep domes apparently of anticlinal structure, which rise as hills above the flatter ground occupied by flaggy dolomites of the ordinary type. The junction of the two types of rock has not yet been seen, so that their relationship is still doubtful.

### *Permian Marl.*

Sherlock. This bed, as in the Nottingham district, is a red marl, occasionally with buff or greenish sandy bands. The thickness remains approximately constant at about 20 ft. between Nottingham and Mansfield. At the latter place it rapidly thins and disappears, so that the Bunter comes to rest directly on the Magnesian Limestone. It sets in again, however, at Mansfield Woodhouse, and is seen at intervals up to the northern boundary of the area surveyed.

Two previously unmapped outliers of the marl have been traced. The first, brought in by a fault, occurs at Sutton-in-Ashfield, where it is exposed in the Great Northern Railway cutting. The second covers much of the parkland at Park Hall, north of Mansfield Woodhouse.

## TRIAS.

### *Bunter.*

Sher- The Lower Mottled Sandstone is about 90 to 100 ft. thick between Kirkby-in-Ashfield and Warsop. It is exposed in

several sand-pits, the largest of which, at Mansfield, has a working face about 75 ft. high. This excellent section shows about 40 ft. of Pebble Beds of a pale-red colour, resting with a sharp junction on deep-red Lower Mottled Sandstone. The boundary of the two is eroded and the unconformity is very striking, although local.

At Mansfield, the Lower Mottled Sandstone rests with a slight unconformity directly on the Magnesian Limestone, as can be well seen near Hallam's Grave, a mile N.E. of the town.

The Bunter Pebble Beds cover most of the area of Sherwood Forest, but there are few sections except those exposed by the railway cuttings on the Midland Railway from Mansfield to Southwell, and on the Great Central line from Warsop to Ollerton. In these sections the rock is a pinkish, or buff, sandrock, with scattered pebbles, and usually with a strong current-bedding dipping on the whole towards the east. Strings and lenticles of pebbles are of frequent occurrence, and broken lumps of red marl, indicating contemporaneous erosion, are locally abundant, sometimes in well-defined bands.

Impersistent partings of marl, a few inches in thickness, are occasionally present in the Pebble Beds and are probably the cause of the small springs that ooze out in a few places in the midst of the sandy country. A band of green and red marl of exceptional thickness and extent, which occurs in the Pebble Beds, two-thirds of a mile N. of Blidworth has been traced for over a mile. There is at present no clear section along its outcrop, but its thickness in places must reach some feet, as a small brickyard was formerly worked in it at a place still known as Brickkiln End.

In the neighbourhood of Farnsfield and Bilsthorpe the upper portion of the Pebble Beds forms a well-dissected plateau, sloping, with the dip, to the S.S.E. In this tract quartzite pebbles are often so numerous at the surface as to suggest the presence of a thin veneer of glacial drift, especially as they are associated with many blocks and fragments of white and yellowish sandstones of Carboniferous origin, but this covering is rarely thick enough to be mappable. A shallow depression between the gentle dip-slope of the Pebble Beds and the gentle rise formed by the lowest beds of the Waterstones marks the junction of the Bunter and Keuper. Along this line the saturation water-level frequently reaches the surface, giving rise to springs or marshy ground. The actual junction was seen 550 yds. W.S.W. of Bilsthorpe Church, where red Bunter Sandstone is overlain by the basal Keuper conglomerate with a green sandy matrix. Mr. Smith

The Pebble Beds mapped in the Ollerton district resemble those above described. The local details will be recorded in the forthcoming Memoir on the district. Mr. Lamp lu

*Keuper.*

Traces of an impersistent basal conglomerate resting upon the Bunter Pebble Beds were seen at a few other points besides Mr. Smith

that above mentioned, and borings have also proved its sporadic development. Some degree of unconformity between the two divisions is further suggested by the manner in which the Waterstones seem to occupy depressions in the Bunter, and by the way in which features in the latter strike against the outcrop of the former.

Between Farnsfield and Edingley the lower portion of the Waterstones takes on characters which allow it to be mapped as a distinct sub-division. It consists of from 18 to 20 ft. of grey-green shales, loams, and thin sandstones, with occasional red layers, and with obscure fragments of plants. Near Farnsfield these beds are worked as pottery clays, but the base is nowhere reached. The green beds appear to lose their importance when traced in a south-westerly direction to Coombs Wood.

These beds are succeeded by Waterstones of normal type, consisting of irregular intercalations of red marl and brownish red and grey soft sandstones. Sandstones of this series are well exposed in the Edingley Hill road-cutting, and they elsewhere produce scarp and dip-slopes and occasionally form the capping of isolated, almost flat-topped, hills. Upper Hexgrave stands upon an outlier of these beds resting upon the green shales. Towards Bilsthorpe and Eakring the principal sandstones occur at two horizons, and therefore give rise to two distinct features separated by softer beds, the higher being near the top of the division, and the lower rising steeply above the gently sloping outcrop of the green beds.

Lamplugh. The green beds at the base of the Waterstones are continuous from Bilsthorpe up to the northern margin of the map, and are exposed in small brickyards at Wellow and Bothamsall. Their junction with the Bunter, except where obscured by alluvium, is always sharply marked by the change from sandy to clayey soil, and this geological boundary therefore constitutes the boundary between tracts of very different agricultural character. The above-described double feature due to the two principal belts of sandstone in the Waterstones is very conspicuous between Eakring and Wellow. There is, however, so much marl intercalated with the sandstones that stiff soils predominate over the whole outcrop of the Waterstones, even where the sandy beds immediately underlie the surface.

Smith. Judging from borings, the Waterstones are thickening rapidly northward from the Greet Valley where they are about 180 ft. in thickness. The line of division between them and the overlying marl is, however, not well defined lithologically, and is difficult to trace.

The main outcrop of the Keuper Marls N.E. of the Greet Valley forms a much-dissected plateau showing a gentle south-easterly dip. The dip of the marl increases decidedly as the Trent Valley is approached. The greater part of the area being practically free from drift, it has been found possible, by means of the slight features to which they give rise, to

trace fairly continuously the thin sandstones, or "skerries," which are intercalated with the marl. When this is done, it is found that there are five separate horizons at which there is a considerable but locally varying proportion of sandstone associated with shaly marl. These bands were followed over some 24 square miles of country, and proved to be unexpectedly persistent. The lower three, where the dip is gentle, form little plateaux with terraced slopes descending to the valleys. The sandstones of the two higher groups differ in lithological characters from those below, and it is therefore generally possible to identify the first or lowest band of the higher series. This band, which lies at approximately 230 ft. above the base of the marls, forms the top of Mickleborough Hill and has been traced over a wide area, giving a useful clue to the structure of the district, which is otherwise masked by the general uniformity of the marls. In this manner it is found that the rocks are gently rolling, with the axes of the folds at right angles to the general strike of the beds.

Gypsum occurred at several horizons, but in workable quantities only near the top of the marls at Newark. The tea-green marls at the summit of the series—so persistent throughout Leicestershire—are still continuous, though diminished in thickness, along the eastern side of the Trent Valley.

### *Rhætic and Lias.*

Mr. Smi

The Rhætic escarpment north of Newark is much less conspicuous than in its range south of that place. In the area surveyed between Newark and South Collingham, it has been breached in two places, east of Winthorpe and Langford respectively, and swamped by sheets of post-glacial river-gravels which have completely surrounded islands composed of Rhætic beds and Lower Lias limestone. The two small tracts of Lower Lias that have been surveyed call for no special remarks. Their outcrop is to a large extent obscured by glacial gravels.

## PLEISTOCENE AND RECENT.

### *Glacial Deposits.*

Mr. Lan
l

The same anomalous conditions with respect to the Glacial deposits of the North Midlands that were commented on in the SUMMARIES for 1905 and 1906 were again found in the tracts mapped during 1907. By far the greater part of the country examined is driftless or contains a mere unmappable sprinkling of extraneous material, while in a few isolated localities, usually elevated somewhat above the surrounding ground, there are indubitable glacial deposits which indicate that most, if not all, of the driftless country has likewise been glaciated. Whether the remaining patches are the relics of a once-extensive sheet, or whether the drift has been piled up

locally where now found and has never been deposited in much quantity elsewhere is still open to question; but the evidence on the whole favours the view that, while the existing patches have been considerably reduced by denudation, it is only at these places that there has ever been much accumulation of glacial detritus, the ice having elsewhere swept over the country and disappeared without depositing sufficient material to leave a lasting record. The mass of drift at Blidworth described below is especially instructive in this respect, as it contains numerous big erratics, including many of Lake District type, which would endure for a long time as a local cluster even if their clayey matrix were denuded away. Similar boulders are dotted sparingly over the country northward between Blidworth and Mansfield, and still more sparingly eastward between Blidworth and Farnsfield, but they are nowhere so abundant as to suggest the former presence of such a mass of drift as that at Blidworth. This mass probably represents an exceptional accumulation at the edge of the north-western ice-sheet during a pause in its recession.

However to be explained, it is evident that the Blidworth drift, at an elevation of 500 ft. above O.D., and the gravelly drift on the Keuper Marl plateau between Kneesall and Kersall (see below) at about 300 ft. above O.D. are the principal factors to be taken into account in studying the glaciation of this part of Nottinghamshire.

Some observations on the different tracts surveyed during the year will be recorded in the order of their local occurrence from west to east.

Wedd. In the Matlock district of Derbyshire north-west of Ashover, a tract of drift extends up the valley of Smalley Brook, the eastern of the two principal streams that unite to form the Amber. The upper part of this valley from the neighbourhood of Brockhurst northward is completely filled with boulder-clay, which, creeping up the slopes and spreading outward up to the escarpments of the Kinderscout Grit, reaches an altitude of nearly 900 ft. This boulder-clay stretches westward of Uppertown into and beyond the valley of the western stream, Hodge-lane Brook. It consists of a stiff grey clay full of angular fragments of various Carboniferous grits and sandstones, the finer ones sometimes faintly striated, with some chert and rarer limestone-boulders.

Gibson. The eastern part of the Derbyshire Coalfield is remarkably free from drift, or indeed from any signs of glaciation. Near Kirkby and Pinxton Station two limited patches of drift, consisting of sand and gravel overlain by red clay with stones, lie at the foot of, and are banked against, the Magnesian Limestone escarpment. The stones contained in this drift include a few far-travelled rocks, probably from the Lake District, but the majority are of local origin. These small patches are evidently the product of the ice-lobe which carries the glacial deposits to the head of the little valley south of the Portland Colliery (see SUMMARY for 1903, p. 17).

In the Mansfield district there is a thin sprinkling of erratic boulders and pebbles over most parts of the outcrop of the Permian and Trias, but the mappable deposits are confined to two or three places only. Of these the most important is the mass previously referred to, at Blidworth, about four miles S.E. of Mansfield, which has hitherto received only casual mention in glacial literature. Mr. Sher- lo

The drift at this place forms an elongated ridge, about a mile long, trending W.N.W.—E.S.E. It is mainly composed of red boulder-clay, containing numerous erratics which are also scattered abundantly over its surface. On the northern side of the ridge, the boulder-clay appears to rest directly on the Bunter; but on the southern side it is underlain by sandy gravel which extends beyond the limits of the boulder-clay and forms small outliers capping the Bunter on the high ground east of the village. The clay is apparently derived from the Permian Marl, and fragments of Magnesian Limestone are also incorporated with it. The erratics include a few of Millstone Grit and other Carboniferous sandstones, but the majority are igneous, mainly andesites and andesitic breccias, presumably from the Lake District. They range in bulk from about a cubic foot to several feet, the dimensions of the largest that was measured being 3 by 2 by 2 ft.

Another considerable mass of drift, somewhat similar in composition to that of Blidworth, occurs on a ridge of Bunter about 1½ mile due W. of Mansfield, at an elevation of about 550 ft. above O.D. Here again the boulder-clay is underlain on the east by glacial sand and gravel; and it appears to be overlain, also, by a narrow ridge of sand and gravel rising to a height of 600 ft. O.D., which is precisely the height of the drift ridge in Annesley Park, five miles to the southward.

A small patch of sandy drift associated with far-travelled boulders caps the hill near Sookholme, three miles N. of Mansfield, and two more patches have been found in Sherwood Forest, in each case capping a hill. These patches of drift occur at steadily decreasing altitudes as one proceeds eastwards, showing that the dip-slope of the Bunter was in existence when they were deposited.

In the Ollerton district, such drift as there is on the Bunter outcrop is all of a gravelly character, made up almost entirely from Bunter material, and therefore very difficult to distinguish from the ordinary wastage of the Pebble Beds. In many places the occurrence of firm Bunter sand-rock close to the surface proves the absence of drift, and the prevalence of this condition is still better shown by the sharp change, previously referred to, in the character of the soil along the junction of the sandy Bunter with the clayey Keuper. But there are other tracts, especially along the outer rims of the principal valleys, where the soil is so full of stones, including some not likely to have been derived from the Bunter, that the presence of gravelly drift is suspected. Sections are unfortunately rare, but in two or three small gravel pits it is see[redacted] Mr. Lam lu

that a few feet of pebbly rubble lies irregularly in "pipes" and "pockets" on the Bunter sand-rock, as, for example, in the pit at the cross-roads at the N.W. corner of Rufford Park, and in the pit E. of Warren Farm, Haughton. Whether such deposits be due to the direct agency of the ice, or to glacial or later river-floods, they are evidently of considerable antiquity, for the present valleys have in most cases been excavated since their accumulation.

Small boulders of Carboniferous sandstone, not often more than a foot in diameter, and usually more or less rounded, are scattered over the district in fair numbers, though much less plentifully than in the Mansfield district. The largest boulder of this kind that was seen lay in the previously-mentioned small brickyard near Wellow; it measured 2½ by 2 by 1 ft. Other erratics are conspicuously rare; they include three small boulders of dolerite (the largest, 1 ft. in diameter, at a road-corner in the village of Wellow) and a single block of andesitic-breccia from the Lake District measuring 15 by 9 by 6 inches (in a pond at the corner of a field on the hill near Leyfields, 1½ mile S. of Wellow).

Smith. The almost entire absence of drift is still more marked over the greater part of the Keuper outcrop, as far as surveyed, north and north-west of Southwell, and it is owing to this absence of superficial covering that the harder beds in the Keuper Marl have been able to assert themselves and to stand out prominently as features. There is some evidence, however, for the former presence of drift, for at the base of the alluvium in many of the minor valleys, such as Hockerton Dumble and the valley of the Wink, there is often a stony deposit containing local rubble, Bunter pebbles and some far-travelled boulders (yellow sandstones, basalts, etc.) resting frequently upon a disturbed surface of the Keuper. This deposit suggests that the valleys have been flushed by flood waters at a time when glacial materials still existed within their basins. The absence of big boulders is noticeable, but may be explained by supposing that the drifts were of the character of those still remaining at Kersall Lodge, in which the biggest erratic yet seen was little more than 1 ft. in diameter.

The patch of drift just referred to, and previously commented on, covers the highest ground in the neighbourhood, extending eastwards from Kneesall to Kersall Lodge. At Kneesall it consists of thin boulder-clay, at present nowhere well exposed, but previously seen by Mr. W. H. Dalton, and described by him in the memoir on Sheet 83 ("The Geology of the Country around Lincoln," p. 128), as resting, near Kersall Lodge, upon the sands and gravels which form a long ridge extending from that place to Norwell Woodhouse. The old sections are obscure, but a new section in the sand and gravel west of the Lodge confirms Mr. Dalton's description.

A patch of stratified drift caps a low hill of Bunter sandstone E. of Farnsfield Windmill and is well exposed in a

sandpit, which shews 4 ft. of bedded sand and gravel resting upon the Bunter beds. Some layers of finer sandy texture occurring in the gravel contain numerous small spherical bodies, apparently of concretionary origin, varying in size from a pin's head to that of a small marble, the majority being slightly larger than peas. These curious little spheres have been formed from a fine-grained red micaceous sandstone which was well bedded, and some of the spheres have since broken along the bedding planes. There can be no doubt that they are concretions which have been removed from their original matrix, but the beds from which they have been derived have not yet been identified. Similar concretions were found in the drift at Bobber's Mill, Nottingham, and in smaller quantities at Kersall Lodge.

*Post-Glacial.*

Mr. Smith

The only extensive tract of alluvium mapped during the year is that of the Trent valley below Newark, which is generally similar to that of the same valley between Newark and Nottingham, described in the SUMMARY for 1905. Level spreads and low ridges of gravel and sand, brought down by the Trent when it was a much more powerful river than at present, occupy the greater part of the river-flat; while along both margins of the valley, the gravels are frequently overlain by wide fans of red loam and clay brought in by the small side-streams from the Keuper country. Minor depressions of the gravelly flat have been partly filled with silt, peat and peaty clay, so that there is great variability of soil in this tract. The higher gravels of the Trent spread beyond the low easterly rim of the valley, and beyond the eastern margin of the map. They are considered by Mr. A. J. Jukes-Browne ("Geology of the S.W. part of Lincolnshire, etc.," chap. xi.) to indicate a former course of the river eastward to the Lincoln gap.

In the upper part of the basin of the Greet, around Kirklington and Edingley, there is a flat expanse of gravel which cannot be explained by the present conditions of drainage. It marks a time when strong floods swept the Bunter detritus eastward over the low outcrop of the green clays at the base of the Waterstones.

Mr. Lamp lug

The alluvium of the Maun and Meden in the Ollerton district consists almost entirely of sand and gravel washed from the underlying Bunter Pebble Beds, but in one case where a small tributary has its head on the Keuper clays, a clayey wash is continued down its valley across the Bunter outcrop for more than a mile.

Artificial control of the drainage has given rise to unusual conditions at the confluence of the Maun and Meden near Bothamsall. The streams unite and lose their identity; but at 200 yds. below their confluence, a portion of the water is artificially drawn off into a channel running along the north side of the alluvial flat, which resumes the name of the Meden

while the remainder of the stream, running a parallel course half a mile distant, on the opposite side of the flat, continues to be regarded as the Maun, and the two streams then retain their individuality for a further four miles below their first confluence, when they finally unite to form the Idle.

## ECONOMIC GEOLOGY.

Wedd. *Carboniferous Limestone.*—A celebrated building-stone known as the Hoptonwood Stone is quarried at Middleton and Hopton Wood from the Carboniferous Limestone. The limestone is also quarried in various parts of the district for lime-burning, fluxing, road-metal and other paving, as mentioned in the SUMMARY for 1904.

*Millstone Grit.*—The principal building-stone in the area of Millstone Grit recently surveyed is the Darley Dale Stone (Kinderscout Grit) worked by the Stancliffe Estates Company Limited, at Darley Dale. The Kinderscout Grit is likewise quarried for building-stone at Stanton Moor and Peasunhurst, north of Ashover; and the Chatsworth Grit is worked for the same purpose east of the Derwent. The manufacture of pulping-stones from the Kinderscout Grit by the Stancliffe and other companies is also an important industry, and will be described with detail in the sheet-memoir.

Gibson. *Coal Measures.*—The results of the mapping of the Coal Measures have been previously outlined, and the recent information obtained from borings and sinkings with respect to the underground eastward extension of the Coalfield is summarized in the special article which forms Appendix III. (pp. 137-140) of the present SUMMARY.

Sherlock. *Magnesian Limestone.*—The celebrated Mansfield building-stones, which have been used for important public buildings in many parts of the country, are local modifications of the Magnesian Limestone. Of these, the "White Sandstone" and the "Red Sandstone" are both dolomitic sandstones, differing mainly in colour, and both containing about 50% of silica. They occur at Mansfield, surrounded by normal Magnesian Limestone, and appear to merge into it without definite boundaries. They probably represent a local influx of sandy detritus on the Permian sea-floor.

At Mansfield Woodhouse a fine-grained creamy rock, essentially a dolomite, containing only about 3% of silica, is extensively quarried.

*Permian Marl.*—The Permian Marl is dug in several places near Mansfield for the manufacture of bricks, drain-pipes and roofing-tiles. As the marl rarely exceeds 20 ft. in thickness, it is nearly always quarried to its full depth, so that the clay-pits generally show a capping of sandy Bunter and a hard floor of Magnesian Limestone. In some cases the floor is quarried for building-stone, so that the two industries are carried on together.

*Bunter.*—Being an excellent moulding-sand, the Lower Mottled Sandstone near Mansfield is dug and sent out of the district in very large quantities for this purpose. The largest pit is 500 yds. in width, with a present working face of Lower Mottled Sandstone and Pebble Beds 75 ft. in height. The sand of the overlying Pebble Beds is used as building-sand.

*Keuper, etc.*—In the purely agricultural and sparsely populated Keuper area surveyed during the year, and in the similar adjacent tracts of Bunter, there are a few small brickyards in the Keuper, and gravel and sand pits elsewhere, worked for local requirements only. These have been sufficiently mentioned in the foregoing account of the deposits. Mr. Smi and Mr. Lamplug

## 2.—Southern District—Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Dr. John S. Flett, M.A., Petrographer.
Mr. W. A. E. Ussher
Mr. George Barrow
Mr. D. A. MacAlister } Geologists.
Mr. Henry Dewey

Field-work was carried on during 1907 in two separate areas in Cornwall. In the Lizard (359) Dr. Flett continued the mapping of the serpentine and associated rocks, so that this area is nearly finished, and the whole of West Cornwall will be completed in the coming season. In the other area, including Sheets 336 (Camelford) and 337 (Tavistock), the rest of the officers continued the work of the preceding season. Sheet 336 is nearly completed and will be finished early in 1908; about one-third of Sheet 337 is done. A small area has also been surveyed in Sheet 322 (Boscastle). Mr. Reid

Mr. Ussher was occupied in the preparation of memoirs on the geology of areas surveyed by him near Plymouth and Liskeard, St. Austell, Ivybridge, and the Quantock Hills.

### Serpentine and Associated Rocks.

*The Southern Lizard District.*

During the summer of 1907 Dr. Flett continued his revision of the crystalline rocks of the Lizard, the area surveyed being principally along the northern boundary, where the hornblende schists and mica schists are in contiguity with the Ordovician and Devonian rocks of the Helford river district. About four-fifths of the area have been completed; the part still unsurveyed lies around Coverack, and includes some of the most debateable ground, but the conclusions arrived at from the evidence already examined may be briefly stated. Dr. Flet

The aureole of schists that lies around the great intrusive stocks of the Lizard consists of both sedimentary and igneous rocks. The former are mica schists, granulites and thi

quartzites, the latter are hornblende schists some of which are believed to be intrusive (from the remains of original structures occasionally preserved) while others accompany the sediments in such a way as to make it likely that they are interbedded lavas. There are also mixed types of rock which have probably been ash beds or ashy grits. The whole of these schists have undergone profound metamorphism partly of a thermal and partly of a dynamic type. The sediments contain cordierite, andalusite and sillimanite, minerals which indicate the operation of high temperatures, while in the igneous schists there is abundance of green pyroxene, garnet and epidote, which may have the same origin. They have also been greatly folded and crumpled, though often in the sediments the bedding is still very perfect. In fact, these rocks attained their present state by being folded and rolled out when very hot.

An incomplete girdle of schists surrounds the crystalline bosses or stocks. Of these latter the serpentine preceded the gabbro, which in turn is cut by diorite and granite. The succession given in last year's SUMMARY OF PROGRESS (p. 30) holds good generally, but there are two gabbros, one of which preceded the serpentine, and probably also two sets of granite instrusions All of these rocks frequently show foliation or gneissic character; they also yield types which are nearly or completely massive. In some parts of the Lizard the foliation is persistent and uniform; in others it appears and disappears suddenly and is singularly inconstant. Each of these stocks has one margin well foliated, while on the opposite side massive rocks predominate. The gabbro cuts the serpentine; the diorite and granite vein the gabbro; and in each case the dykes or sills may be either perfect gneisses or nearly normal igneous rocks. The so-called "granulitic series" is the foliated gneissic margin and peripheral offshoots of a group of granito-dioritic injections.

The banded structures are variable and complex; no simple explanation will suffice for all the phenomena. In some the foliation is due to fluxion; in others to *lit-par-lit* injection. Movement under pressure, segregation in the solid and differentiation in the liquid state, account for part of the facts. In the sedimentary schists the bedding must also be taken into account. It is possible also that some of the earlier intrusions have been partly incorporated or resorbed by the later. Clear evidence of these agencies having been at work can be pointed out again and again; where they have co-operated it is often impossible to unravel the history of the complex and to assign to each its share in the final result.

A point of great importance in the theory of the Lizard metamorphism is the question at what time these rocks assumed their foliation. The evidence, though involved, proves that the foliation in the intrusives is of the same age as the rocks themselves. The different members of the succes-

sion were foliated at the time they were injected, or very shortly thereafter, for the next succeeding intrusions cut the foliation of their precursors and often do not share in it. Massive gabbro cuts foliated serpentine, and massive diorite intersects foliated gabbro. In more than one instance the later parts of a group of injections traverse the foliation of the earlier members of the same series. It is known that powerful earth pressures affected the Lizard at two distinct periods after the intrusive history was closed. These have produced displacements, granulitization and shearing; their effects are often seen, but the main foliation is primal. It was of inter-current and not of subsequent development.

Very remarkable phenomena of another kind are shown by some of the Lizard injections and have been described by many of the geologists who have studied the intrusive complex. The dykes and sills may be highly foliated while the rocks they penetrate are massive or nearly massive. The gabbro may be an augen gabbro or gabbro schist, the granulitics a perfect banded gneiss, where the serpentine, which they cut, is perfectly massive and shows its original fluxion structures. This problem is too intricate to be discussed here, but it is believed that the foliation in these cases is partly an injection and partly a pressure effect.

The crystalline stocks of the Lizard have been intruded during a period of movement. Folding accompanied injection, or, more properly, perhaps, alternated with it. There were epochs when the regional pressures were high and the rocks were deformed and crushed; while at other times the pressure was relieved and igneous magma flowed in, to consolidate as normal igneous rocks. The movements were repeated many times, and were interrupted by periods of rest; they continued after the igneous history was ended, as the last rocks are sometimes crushed. To these intermittent or spasmodic pressures acting on rock masses in very different states, some solid and nearly cold, others hot and plastic, others still liquid, the structures of the Lizard complex owe their remarkable diversity. In the great granite bosses of Cornwall we have examples of intrusions belonging to a period when the earth's crust was locally at rest; in Carn Chuinneag and some other Highland orthogneisses we see the effects of movement acting on rocks which had consolidated as normal granites and were long afterwards involved in earth movements. The Lizard belongs to a different type, as its rocks were never massive, but had their foliation and gneissic structures from the first.

The strike of the foliation in the Lizard is not perfectly uniform; this can hardly be expected, seeing the diversity of its origin. There is a general fan structure which produces a dip inwards of the schists beneath the serpentine and gabbro all around the margins, a feature long ago remarked on by De la Beche. But through the whole area there is also a very persistent north-west and north-north-west strike as was

pointed out more than twenty years ago by Dr. Teall.* This strike is very evident in the schists in many places, though disturbed by local conditions and later movements. It ranges through the heart of the serpentine laccolite, being especially persistent in the older portions of that intrusion. It is clear that the formation of the Lizard complex dates from a period when this part of England experienced earth pressure acting in a north-east and south-west direction. In Cornwall, to the north of the Lizard boundary, Mr. Ussher has shown that there are two strikes, one east and west (in North and Mid-Cornwall), and the other north-east and south-west (in South-Western Cornwall). The latter affects only the Ordovician, with possibly some Cambrian rocks (Portscatho, Mylor, Falmouth and Veryan beds); Mr. Hill has proved that this folding is older than the Lower Devonian. In the south-east strike we note the effects of the "Caledonian" movements; they have the right date and the right direction. The east and west strikes of Mid-Cornwall are the well-known "Armorican" or late Carboniferous strikes. The north-west strike of the Lizard schists belongs to an earlier epoch; it is the same as that of the Charnwood Forest rocks, and several Archaean areas in the British Isles.

### DEVONIAN.

In the country north and west of the Camel the boundary between Upper and Middle Devonian has been traced with difficulty, for the thin tuff which acted as a guide for some miles (see SUMMARY, 1906, p. 38) has thinned out, and the line must be drawn in the middle of a mass of grey slate seldom yielding good fossils. Here and there in the St. Mabyn and St. Tudy district characteristic Upper Devonian fossils have been found, and these suggest that the thick lava and tuff there seen do not represent the thin basal mass; they are higher in the series and are perhaps equivalent to the thin band of tuff traced for some distance on the south bank of the Camel between Wadebridge and Padstow. The boundary of the Upper and Middle Devonian appears to pass east of St. Tudy, and to abut against the granite of Bodmin Moor near St. Breward.

If this boundary-line be correct it would follow that the highly-altered calcareous rocks ("calc-flinta") of Camelford and Lanteglos correspond in position to the unaltered limestones of Padstow and of Marble Cliffs on the coast. This view seems to be borne out by the way in which the lava and tuff bands swing round, running approximately parallel to the base now adopted. The absence of limestone in the country between Wadebridge and Michaelstow does not necessarily go against this correlation, for thin limestones tend to be dissolved

* *Geol. Mag.*, 1886, p. 488.

away and to disappear for considerable depths. In this case the calcareous matter may have disappeared over the higher lands, except in places where metamorphism caused by the granite has transformed it into insoluble lime-silicates. There is, however, another explanation of the disappearance of the limestone, and this will be referred to below.

Some distance above the base of the Upper Devonian slates in the country between Pentire and St. Tudy, occurs a thick sheet of pillow-lava, apparently the result of a single submarine eruption from a local vent not far from Portquin Bay. The mass is composed of large isolated spheroids of highly vesicular lava, each with a big cavity in the centre. These central cavities, and also the vacant angular spaces where three adjoining spheroids fail to touch, are now occupied by crystalline calcite; but in many instances the calcite has been replaced by chert; some of the smaller vesicles are usually filled with chlorite or more rarely pyrite. These masses of crystalline almost pure chemically-deposited calcite must be carefully distinguished from the sediment which may be caught up where the lava was in contact with the muddy bottom. True inclusions of sediment seem also to occur; but, in general, subsequent shearing at the junction of the lava and slate has destroyed any evidence of the original character of the contact. Where the undisturbed contact is preserved, the material nipped in between the pillows seems to have been mud, not already hardened slate or shale, and this mud was apparently baked to a slight extent.*

The exact stratigraphical relation of the lava to the surrounding slates was unexpectedly difficult to make out, for it seems that the division between grey slate and purple and green slate, mapped at first as a definite horizon, can no longer everywhere be accepted as such. The pillow-lava over great part of the area occurs in grey slate a slight distance below the purple and green slate; but, in other parts purple and green slate occurs in contact with the lava, even in contact on both sides. This association seemed at first to favour the idea that the pillow-lava is intrusive, like the greenstone-sills. As, however, the purple-coloured slate behaves in the same way to the sedimentary tuffs, we have come to the conclusion that it is the colour, not the lava, which is intrusive, and that the purple and green slates, though usually keeping to about the same horizon, sometimes result merely from a colour alteration in the grey slates. To add to this difficulty, when the purple and green slates are followed northward to St. Teath the purple colour rapidly disappears, being represented in the cliff by a brownish tinge or blotching in pale-green slate. This particular alteration seems, however, to be closely connected with the aureole of metamorphism surrounding the granite; the increase of purple-colour previously described is something different, and we cannot at present offer any

* A paper on "The Origin of the Pillow-Lava near Port Isaac," by C. Reid and H. Dewey, was read before the Geological Society on January 22, 1908.

explanation of it. The Upper Devonian purple and green slates, unlike most purple and green slates and clays in other formations, seem to be of purely marine origin, for they yield trilobites, crinoids and corals.

The well-known limestone of Marble Cliffs and Padstow occurs a short distance below the purple and green slate, and seems to occupy almost the same stratigraphical horizon as the thick pillow-lava of Port Isaac; but the two rocks cannot be found together, though the cliff-sections around Port Isaac are excellent. If we follow the limestone eastward we find that it can be recognised at Porthilly, at Dinham Mill, and for about a mile east of Wadebridge. There the lava commences, and the limestone is entirely lost till we get to St. Teath, where the volcanic rock disappears. Close to St. Teath we find an extensive metamorphosed calcareous mass (the "calc-flinta" mapped by Mr. Barrow) apparently coming on at about the same horizon in the Upper Devonian. It looks as if the lime of the limestone had entirely migrated into the cavernous lava over the whole area where the lava occurs. On the other hand, it may be suggested that the limestone is largely a precipitate caused by the submarine eruption. We cannot say which view is right; but at any rate there seems to exist a close connexion between the lava and the limestone. The proximity of the limestone accounts for the enormous quantity of lime now found in the vesicles. In another lava-stream north-east of Camelford the amount of calcareous matter is so great that the rock has been burnt for lime, though not with much success.

Black slates with *Styliola* and bands of limestone occur on the east of Wadebridge, nearly as far as Croanford. They resemble the Upper Devonian slates of the banks of the Camel west of Wadebridge, and like them are invaded by sills of greenstone. The beds bend round near Croanford, strike in a north-north-east direction, and are succeeded eastwards by slates very similar in character, but apparently non-fossiliferous. As the granite is approached the dark slates become metamorphosed, and even outside the aureole of certain metamorphism a wide area of slate with a satiny lustre on the cleavage-planes can be traced. These slates seem to be affected by the granite, though no contact minerals can be found in them.

When the petrographical characters of the rocks which encircle the north of the Bodmin Moor granite mass are examined they are seen to differ entirely from those already described, and the correlation of the two facies is a matter of difficulty. Instead of the comparatively unaltered grey and variegated slates and associated tuffs and lavas there is a series of sheared phyllites and volcanic rocks, which in almost all localities is greatly metamorphosed, with development of new minerals.

These rocks have been traced from Tremear westward towards the coast, and everywhere present the same characters.

Mr. J. Parkinson* divided them into seven well-marked types, which are recognised in numerous localities. Most persistent of these is a band, in places nearly a mile wide, extending from St. Clether to the coast, of highly-sheared lavas and ashes, grey-green in colour and often amygdaloidal. Pillow-like forms are well displayed in the high crags which flank the river Inny, near St. Clether, and also in a disused lime-quarry by Davidstow Post Office. Hand specimens show abundant bronzy-brown mica-scales which glimmer on the cleavage faces and can be recognised in the mud derived from the decomposed rock. Calcite and chlorite fill the amygdules; the former often occurring in considerable quantity, as can be seen on the shore at Trebarwith Strand.

North and south of these volcanic rocks blue-black even-grained phyllites can be traced, and these are flanked by grey-green phyllites with Upper Devonian fossils.† Between Tremear and Davidstow all these beds have a cleavage-dip north-north-east at about 25°, but the strike changes to due east and west, and then swerves round through S.W. and N.E. until it is nearly north and south on the coast.

From Woolgarden Farm to the coast an easily recognised and persistent band of grey, banded phyllite, often arenaceous and always spotted with small seed-shaped minerals, may be traced. In the village of Trewassa these rocks have been quarried for building-stone, and the various pits reveal abundant sections of their mode of occurrence and supply fresh specimens for slicing. Petrographical examination of them under the microscope has not yet been made, but Mr. Parkinson‡ describes the mineral which occurs as spots in them as clinochlore.

By Condolden Barrow the same type is seen in the ploughed fields, and in several places a little west of Delabole it also occurs.

Beneath the grey-green fossiliferous type above mentioned, dark grey highly micaceous phyllites are found, which are well exposed in the neighbourhood of Slaughterbridge. Traced towards the granite mass the beds become metamorphosed to typical mica schist with chiastolite. The mica schists are described on p. 36 by Mr. Barrow, and further description is here unnecessary. South of the Slaughterbridge type the well cleaved blue-grey pyrite-spotted slates come on. They are extensively quarried at Delabole, and at one time were quarried in several large pits between that place and Tintagel. The exact relation between the Slaughterbridge and the Delabole beds is vague, the one type apparently graduating insensibly into the other.

Penetrating the Slaughterbridge beds, sills, often of considerable width and much metamorphosed, can be traced in

* *Quart. Journ. Geol. Soc.*, vol. lix., pp. 408–428, 1903.
† S. R. Pattison, *Quart. Journ. Geol. Soc.*, vol. x., p. 247, 1854.
‡ *Op. cit.*

the fields. The rock is extremely hard and resists blasting and quarrying operations.

A sheared igneous rock is found in the same beds at Worthyvale and south of Villaparks; the slate at the latter locality contains garnets.

Slates of the Delabole type occupy a wide area southwards towards St. Tudy, and are altered by a large mass of greenstone covering many acres and composing the hill-ridge of Michaelstow Beacon.

The correlation of the beds of this district with the slates of the area comprised by the parishes of St. Minver, St. Endellion, St. Kew, etc., is attended with difficulty. Fossils are scarce and badly preserved when found, but the evidence derived from them, scant as it is, indicates that the rocks of the whole area are of Upper Devonian age, but the relative position of the beds cannot yet be determined with accuracy.

Alister. In the region lying east of Bodmin Moor and around Callington much difficulty has been found in distinguishing the various divisions, and until the mapping is further advanced not much can be said about it. The question of the exact relation of the Carboniferous to the Devonian strata is further complicated by the probable occurrence of a double unconformity.

The Upper Devonian rocks in this area are represented by shales with contemporaneous pillow-lavas and tuffs. The sediments are of fine texture, with tints varying from dark-greyish to light-buff or green. In some places a gritty facies occurs, with local developments of grit bands (*e.g.*, near Callington). Unless these grits are infolded Upper Carboniferous they must be regarded as belonging to the Upper Devonian, perhaps corresponding to the thin grits seen in the Upper Devonian west of Delabole.

The contemporaneous Upper Devonian volcanic rocks comprise schalsteins and pillow-lavas. A fine section of the amygdaloidal lava is exposed in the quarry on the west side of the Lynher, at the edge of the Upper Carboniferous grits at Newbridge. In this and in the abandoned quarry on the opposite side of the Lynher, the pillows, varying in diameter up to 2 ft. or more, are well shown by the concentric rows of round or flattened vesicles filled with calcite, chlorite, and quartz. The calcite appears to be the principal infilling of the vesicles, but it also occurs as well-crystallized veins, and as a decomposition product in the rock. Carbonate of lime of fine saccharoidal texture also occurs in bands, probably as a chemically precipitated deposit subsequent to the consolidation of the lava.

Mixed with basic tuffs and ashes similar lavas also occur in the hill above South Coombe Head, and in a state of decomposition in an irregular patch extending from Venterdon to Oldclims, on the north of Stoke Climsland, at the southern edge of the main mass of the Upper Carboniferous grits. In places these are quarried as freestone.

## CARBONIFEROUS.

### *Lower Carboniferous.*

In this district the Lower Culm has a limited distribution, being represented only by the flinty radiolarian beds of Cadson Bury and Golberdon Downs and by the "decomposed bluish chert-bands" and shales at the side of the road south of Stoke Climsland, described by Dr. G. J. Hinde and Mr. Howard Fox.*

### *Upper Carboniferous.*

Overlying unconformably the Lower Culm cherts is the series of plant-bearing grits and shales to which the term "Middle Culm" is applied by Mr. Ussher. Where the grits are absent there is however some uncertainty in separating the shales from the subjacent older series.

The northern boundary of the St. Mellion outlier, the larger part of which occurs in Sheet 348, on the south, is somewhat irregular and extends from the south side of the river Lynher, west of Newbridge, to the east of Viverdon Downs. Between Newbridge and Tremollet Downs the shales are of dark colour, and it is uncertain whether they belong to the Upper Carboniferous or to the Lower Culm; but the presence of radiolarian shales between Golberdon and the Lynher appears definitely to connect these rocks with the Lower Culm. With the exception of small outlying patches of Upper Carboniferous at Linkinhorne, South Hill, and Stoke Climsland, and of the possible Upper Devonian facies near Callington, already mentioned, no grits occur between those of the St. Mellion outlier and the southern margin of the main mass of the Carboniferous grits and shales, about 1,000 yards north of Stoke Climsland village.

The non-vesicular greenstone sills around Callington are generally much decayed. They are known locally as "free-stones," and are extensively used for building. In the same district occur comparatively fresh ophitic greenstones.

## GRANITE.

The most picturesque portion of the Granite of Bodmin Moor is the area lying to the south of Trebartha Hall, and having an average elevation of more than 900 ft. above sea-level. It is traversed by three long tors or narrow ridges of bare rock, largely built up of huge blocks of granite. These tors rise out of the surrounding smooth undulating ground like long narrow islands from the sea, and in truth this is their real original character, for they did rise as islands, when the thousand-foot platform (described later) was being eroded. The central tor, Kilman Tor, is the most striking of the three,

Mr. Barro

* "Radiolarian Rocks of the Lower Culm Measures." *Quart. Journ. Geol. Soc.*, vol. li., 1895, p. 609.

for with its markedly rounded top, and its sharply-defined steep sides, it bears a striking resemblance to a huge dyke rising through soft shales, but to obtain this effect the rock must be viewed from its east end. The massive aspect of these rocks led to the opening of several quarries served by light tramways. The quarries are now abandoned, but they have proved a curious point; the peculiar flattened ellipsoid form of the blocks in a typical tor is not the result of surface weathering. The same shaped blocks are met with underground, separated from one another by dirt and decomposed granite, which are washed away when the rock is exposed by denudation; the rock then dries, and becomes harder, and is much more able to withstand decomposition. The singular thing about these tor-ridges is the sharpness with which they are marked off from the smoother intervening ground; they are not merely patches left by denudation, they are long narrow belts of sounder rock, more free from cracks, veins and fissures, and better able to resist decomposition than the granite of which the intervening hollows are formed. The persistent stoppage of the decomposition along a definite line is clearly not the result of accident, as the tors are not only roughly parallel to one another but also to the mineral veins of the district.

A comparatively new feature in the granite has been met with during the last season's work, viz., that its boundary with the killas is often a fault. The first illustration of this was met with about two and a half miles south of Camelford. Here the position of the fault is marked by a reef, which crosses the foot of the valley of the Devil's Jump, rising in a large sheet on the western side of the stream and in a smaller reef on the eastern. In a line with this on the opposite margin of the granite is another mass of reef-quartz, so large that it is shown on the one-inch map (Lanlavery Rock) and this, too, lies in a fault between the granite and killas. That they were one and the same fault seemed certain, but further within the granite its position for some distance could not be traced. Nearly half-way between the two localities named are a few isolated ploughed fields, and in these a number of killas fragments were found. They are greatly altered, and mark a small patch of the roof of the granite, thrown down by the fault. This mode of occurrence of a small patch of killas in the heart of a granite area seems unique. The reef contains no ore on the west side, but repeated trials on the east show it to contain copper, and it was mined for some time at the Roughtor Mine, near Davidstow.

Although it cannot be proved, there can be little doubt that the extremely straight margin at the north-end of the granite is also a fault. These faults distinctly coincide with a sudden expansion in breadth of the aureole of metamorphism, as though part of the flat roof were faulted down.

It seems probable that the old copper-lode in Bray Down also occupies a line of fault, for the boundary of the granite

was difficult to trace here, and its probable position is obscured by a great heap of refuse from the mine. In several other places sharp bends in the boundary of the granite are probably faults, but one hesitates to show them as such on the map.

As we approach the old mining centres of Cheesewring and Caradon faults are numerous, and some of them are boundaries between the granite and killas. The first is the great Henwood fault, the length of which is not known, but it forms the boundary of the granite and killas for fully a mile and a half. It has been mined at two places. The next fault is the famous Phœnix United Mine, and this forms the boundary between the slate and granite for over half a mile. Further south, in the South Phœnix Mines, in three cases the lodes occupy faults between the granite and killas. All these faults in the south-eastern part of the granite can for the most part be easily traced at the surface.

In the higher areas, near the sources of the main rivers that drain the district, two well-marked platforms have been met with, both by Mr. Barrow and Mr. Dewey. The higher platform is a little below a thousand feet; the lower keeps very close to the 750 foot contour, and is often still sharply defined on both sides of the northern part of the Bodmin Moor Granite. These have a special economical importance, as the ground above the 750 foot platform has been exposed to the agencies of denudation for a considerably longer period than the ground below it. In this higher ground there is now left a far larger amount of débris from the granite, which has collected on low slopes above the distinctly alluvial deposits, more commonly worked for stream-tin. Where this débris or wash occurs immediately below small strings or veins of tin and wolfram, it is locally so much enriched by them as to be worth working. A paper has been read by Mr. Barrow before the Geological Society dealing more fully with these subjects, and will be shortly published in the Society's Journal.

### THE AUREOLE OF METAMORPHISM.

The tracing of the aureole of metamorphism round the Bodmin Moor Granite has been continued, and a large amount of material obtained for future examination. On the west side of the granite, owing to the Pleistocene uplift, the Camel has recently deepened its bed considerably, and has thus exposed a large amount of fairly fresh rock from which good specimens can be obtained. All along the north end no such recent excavation has taken place, and we are forced to rely on outcrop specimens, except in the case of a few artificial openings or quarries. This continues all along the east side almost to Trebartha Hall, where we once more enter the area of recent deepening of the valleys, and the exposure of sounder rock. In this part of the outcrop artificial exposures are rare, but the few that do occur are in specially interesting rocks.

About Wenford Bridge the aureole still maintains its pre-

vious breadth of about three-quarters of a mile, but further north, after crossing the fault previously described as traversing the granite, it suddenly broadens, and at Lanteglos it has a breadth of about a mile and a half. This increased breadth is maintained all along the north end of the granite, and does not sensibly diminish till the fault is again crossed in the neighbourhood of Bray Down, when it resumes approximately its normal dimensions, to which it adheres as far as it has yet been traced. In the first part of the aureole the plane of junction of the granite and killas is clearly seen to be extremely steep, but after passing the fault it seems as if it descended by a series of steps and the first step had been somewhat thrown down by the fault.

Owing to the fact that the Camel flows in a nearly straight line, north and south, and that the margin of the granite is strongly curved, the river twice cuts completely through the aureole of metamorphism, exposing the contact of the granite and the killas in one place. The rocks thus exposed are mainly altered calcareous shales, now represented by andalusite and chiastolite-bearing rocks of the ordinary type and calc-flintas and flinty biotite rocks. Specially fine examples of the latter have been obtained from an old mine, and these show the typical flinty cross fracture, though the biotites have a marked parallel arrangement. The most interesting rocks, however, are the calc-flintas which as usual vary rapidly in the details of their composition, though certain dominant minerals form a fairly large portion of all specimens. There are two zones of this type, but the higher is the more interesting. Specimens of it taken from the quarry a little north of Camelford have been described by J. A. Phillips, and the fact that garnets are present in the rock was noted. A far more interesting exposure of the same beds occurs in two quarries, one on each side of the road, close to a small stream about a mile east-by-north of Camelford. Here the calc-flintas are much more crystalline and the garnets in the body of the rock, larger and more conspicuous. In the cracks or joints, by which these calcareous rocks are traversed, idiormorphic crystals of pale coloured idocrase are fairly common, while garnet and epidote also occur in considerable quantity. These minerals are best seen when the joints are filled with soft brown dirt; for the latter can be easily washed away and the crystalline faces of the minerals laid bare. The original infilling material of the cracks appears to have been calcite, and when still preserved the outlines of the idocrase and epidote crystals are no longer so well seen, but they are better preserved. The calc-flintas of the Camelford area are considered by Mr. Dewey to be of Upper Devonian age.

### MINING INFORMATION.

A feature of the granite in the Altarnun area is the occurrence of a great amount of wolfram in the veins; at one time a great hindrance to profitable working, it is now worth more

than the tin itself. The mines in which the trend of the veins is east-north-east may be taken in order from north to south.

Trewint Down.—This lies on the north side of the stream above Trewint Marsh. Old shallow workings are numerous in it and recently an adit has been driven, starting just above the stream; but the work has not been persevered with. It is said to be a nest or plexus of small strings rather than a solid vein. The total amount of work done in it is not large, and no engine house has been built.

Vincent Mine.—The lower of the two stone-built engine house above Trewint Marsh stands on this vein, which runs for some distance along the alluvium of the stream; it was met with by the streamers, and known formerly as the "Streamers-Vein." By its decomposition it set free a great quantity of tin and wolfram which was got by the streamers. The mine itself is said to have paid when prices for tin were good, but it was handicapped by the large amount of wolfram met with. This was specially abundant at the twenty-fathom stope and was thrown aside, and is said to be loose there now; so far this mine has not been restarted.

Horsbro Mine.—This vein is met with on the south side of the road close to the higher of the two stone engine houses, and the shaft is sunk on the back of the lode, as can be seen by looking down the pit. Tin and wolfram both occur here, as well as some copper. Very fine specimens of wolfram were obtained from this vein, and were thrown on the north side of the road. Till the mineral suddenly became valuable, any one without trouble could find a fine specimen showing large crystals; now it has all been collected. The mine was being pumped dry at the time of our visit.

A little further south another small vein occurs of less value than the Horsbro; its position is quite clear from the line of old pits on the ground; in which a considerable amount of wolfram was encountered.

Halvanna Downs.—Two veins occur further south on Halvanna Downs; the northern vein was followed by the old workers for a great distance, but the more modern and deeper workings are said not to have been so successful.

The more southerly vein has not been followed to so great an extent.

Returning to the eastern margin of the granite, three veins occur close together and approximately parallel in the ground above the stream opposite the second mill below Trewint, the whole forming the mine of Wheal Annie. These veins were worked "open-work," and the workings are still more or less open, especially close to the farm house. The tin ore here occurred in bunches, and some of the crystals were specially large. A fair amount of wolfram accompanies the middle lode. Quite close to the stream at this locality a manganese vein was cut and worked to some extent. It is in a later north and south lode; the manganese is said to have occurred in large lenticular patches. Much of the ore is still lying about and good specimens can be easily obtained. The op[illegible]

work lode lies almost in a line with a copper lode once mined further up the hill to the south-west. It was not extensively worked, and is said never to have paid.

Lemarne Mine.—The next vein formerly worked occurs in the hill-side a little north-west of Trebartha Hall; the deepest shaft here was only some thirty fathoms. Tin and wolfram were both met with, but the mine is said to have been stopped as being a great disfigurement to the Hall.

### 3.—South Wales District—Pembrokeshire.

Dr. Aubrey Strahan, M.A., F.R.S., District Geologist.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A., B.Sc.
Mr. O. T Jones, M.A., B.Sc.
} Geologists.

The field-work of 1907 lay in the Lower Palæozoic rocks around Haverfordwest, on the Old Red Sandstone and Lower Carboniferous rocks bordering Miford Haven, and on the Coal Measures near Cresswell. Mr. Cantrill was engaged upon Silurian and Ordovician rocks in Sheets 228 and 227, while Mr. Thomas was surveying the Ordovician and Cambrian along the northern margin of the same area. The southern part of the Ordovician and Silurian tracts, together with part of the area occupied by Carboniferous rocks and Old Red Sandstone, was examined by Mr. Jones. The surveying of the Coalfield was continued by Dr. Strahan, and that of the country around Pembroke by Mr. Dixon. The examination of the igneous rocks of the district was commenced by Mr. Thomas and Mr. Jones.

#### CAMBRIAN, ORDOVICIAN AND SILURIAN.

The following table shows in descending order the succession of the rocks below the Old Red Sandstone;—

| | | |
|---|---|---|
| Silurian (part). | Ludlow-Wenlock? | Greenish-grey siliceous sandstones and mudstones, fossiliferous. |
| | Llandovery | *Upper Llandovery.*—Yellow sandy mudstones, alternating with thin bands of sandstone, and having coarse grits and conglomerates at the base. Fossils *e.g. Pentamerus oblongus* abundant. |
| | | *Middle and Lower Llandovery.*—(4) Green mudstones, fossiliferous (Millin Group); (3) Gasworks Sandstone; (2) Green mudstones, fossiliferous in the upper part; (1) Blue-black shales, including bands of sandstone and conglomerate. |

| | | | |
|---|---|---|---|
| Ordovician | Bala | *Slade and Redhill Beds.** | |
| | | *Shoalshook & Robeston Wathen Limestones.* | |
| | | *Dicranograptus Shales* (upper part). | |
| | Llandilo | *Dicranograptus Shales* (lower part). | |
| | Arenig | *Llandilo Flags.* | |
| | | *Didymograptus-bifidus Beds.* | |
| | | *Tetragraptus Beds.* | |
| Cambrian (part) | Lingula Flags | Flaggy shales, yellowish-brown and grey, weathering to a dull yellow colour; *Lingula* and Olenoid trilobites. | |

CAMBRIAN.

*Lingula Flags.*—The *Lingula* Flags, as developed in the district recently surveyed, are yellowish-brown and grey flaggy shales, often containing much mica and weathering to a dull-yellow colour. They generally yield *Linguloe*, and olenoid trilobites may be obtained from several localities. Mr. Thom

These flags and shales have been traced, on the north side of the igneous rocks mentioned below, from the neighbourhood of Spittal Cross to Wolfsdale, by way of Trefgarn Bridge and Lewiston, but as yet their more westerly extension is unknown. Their southern boundary, for the whole of its course, is formed by a thrust which has thrown them into contact with the volcanic series.

ORDOVICIAN.

*Tetragraptus Beds.*—In the Summary of Progress for 1906 the outcrop of these beds was traced from Henllan Amgoed, north of Whitland, to the valley of the Western Cleddau, north of Haverfordwest. On the western side of that valley they have been followed in a westerly direction, by way of Wolfsdale, Robleston, and West Dudwell, as far as the survey has advanced, and were last seen at Frog's Hole, near Cuffern House. The outcrop of these shales is persistent, but between the River Cleddau and New Inn, north of Camrose village, has an average width of only about 100 yards.

The *Tetragraptus*-beds are bounded on their southern side by the *Dicranograptus*-shales, over which they have been thrust; to the north they dip towards a series of andesitic lavas and tuffs, but the boundary is almost always a fault of which we are unable at present to judge the magnitude.

The shales are remarkably constant in their lithological and palæontological characters, preserving the usual blue-black

* The general characters of these and the other Ordovician subdivisions were given in the "Summary of Progress for 1906," p. 44.

colour throughout their course, and containing the same extensiform species of *Didymograptus*.

*Didymograptus-bifidus Beds.*—These shales have, so far, not been met with to the west of the Western Cleddau, and were last seen on the eastern side of the river in the new railway-cutting below the Spittal Road. The Camrose anticline, described below, has not been eroded to a sufficient depth to allow these beds to appear below the Llandilo Limestone (p. 41).

Their disappearance west of the tunnel near Trefgarn Bridge is due to the *Tetragraptus*-beds having been thrust over them from the north on to the *Dicranograptus*-shales. It is possible, however, that as the survey progresses other lenticles of *D. bifidus*-shales may be found to occur along the line of thrust.

In the course of work to the south of Milford Haven on the Lower Palæozoic inlier which extends continuously from Freshwater East to Freshwater West, it has come to light that Ordovician rocks are brought to the surface by the folding, as well as the Silurian hitherto known.

Unfortunately the older rocks are poorly and infrequently exposed, and are concealed at the coast by blown sand. In a stream at Kingsfold Bridge they have yielded a graptolite which has been identified by Mrs. Shakespear as *Didymograptus artus*; they are therefore referable to the *Didymograptus-bifidus* Beds (Arenig), with which they agree exactly in lithological character. Whether, however, all the Ordovician rocks which reach the surface belong to this zone is at present unknown. Their junction with the Silurian is nowhere visible, but the form of its outcrop points to its being original and not a fault. It is readily traceable on the ground, for the hard Silurian sandstones and mudstones form steeply rising ground, whereas the soft shales which constitute the Ordovician give rise to wet clay-land, many springs, either potable or chalybeate, being thrown out along the boundary itself.

The mapping shows, furthermore, that Ordovician rocks crop out over two detached areas which are bounded by the sea at Freshwater East and Freshwater West respectively. Though the Ordovician shales in the cores of the folds may be contorted, the Silurian rocks are not affected in this way; their thickness therefore may be estimated from their width of outcrop. In this way it is found that in the Freshwater East area they vary in thickness from 250 to 600 ft., but that in the western area, though they may have a thickness of 500 ft. or more along the northern side, they are either absent or merely a few feet thick along the greater part of the southern side.

This marked variation may be due to two causes. It is evident from the fact that the Silurian rocks succeed the Arenig almost, if not quite, immediately, that there is an unconformity between the two. Also, it has been found that at Freshwater East the Old Red Sandstone basal conglomerate rests sharply on Silurian rocks of normal marine type, the

thick group of passage-beds present in the Llandilo district being absent. Apparently therefore this junction, also, is an unconformity. An unconformity at either the top or bottom of the Silurian would account for its variation in thickness.

*Llandilo Flags and Limestones.*—A mass of limestones and flags is brought up in the core of a gentle anticline to the north and south of Camrose village. The beds are well exposed, and have been quarried along the main road going north from the church, and also in the deep road-cutting between the church and Camrose Brook. Mr. Thom

The limestone occurs in a succession of bands ranging up to one foot in thickness. It is blue in colour when unweathered, but, like all the other masses of Llandilo Limestone previously described, is largely converted into an ochreous rottenstone.

Towards its upper limit it becomes more flaggy in character and darker in colour, showing its approach to the dark sandy *Dicranograptus*-shales, into which it passes by insensible gradations. This passage is well seen in the banks of the Camrose brook and mill-race.

*Dicranograptus Shales.*—The *Dicranograptus*-shales west of the Western Cleddau occupy a considerable area around the Llandilo limestones of Camrose and the Redhill Beds of Keeston. They occur between the *Tetragraptus*-shales on the north and the Redhill Beds of Redhill and Pelcomb Hill on the south.

They are well exposed along the western bank of the River Cleddau, and in almost all the small streams, such as the Wolfsdale, Camrose and Knock brooks, which flow eastward into the main valley. They present the usual lithological characters, and contain a great number of graptolites belonging to several genera.

There is little doubt that most of these shales are referable to the Glenkiln stage of the Llandilo, and the distribution of the graptolites proves more or less conclusively that the Redhill Beds which succeed them do not always rest upon the same horizon.

A small area of *Dicranograptus*-shales is brought up along a line of fault which crosses the Cartlett valley at Shoalshook, and extends thence in a west-south-west direction to Prendergast, the northern suburb of Haverfordwest. They are well exposed in Shoalshook farm-yard, where they dip northward under the Shoalshook Limestone of the adjacent railway-cutting. They have yielded a few ill-preserved graptolites which await identification. At Prendergast they are better exposed, but are equally poor in identifiable fossils. Mr. Cantri

*Robeston Wathen and Shoalshook Limestones.*—At Shoalshook the latter of these limestones is brought up by the same belt of faulting which has revealed the *Dicranograptus*-shales, and is excellently exposed in the railway-cutting. It consists of about 250 ft. of sandy and calcareous flaggy mudstones, blue-hearted but weathering yellow, with bands of tough blue limestone-nodules. The beds have yielded to various collectors

a long list of fossils, including *Trinucleus seticornis*, *Illænus boumanni* and other trilobites.* A new point connected with the limestone is the fact that at Shoalshook it has yielded a few ill-preserved graptolites to Mr. John Pringle.

At Prendergast Place the Shoalshook Limestone overlies the *Dicranograptus*-shales, and is succeeded by the Redhill Beds.

At Pelcomb, 2½ miles north-west of Haverfordwest, the Redhill Beds rest directly against the *Dicranograptus*-shales without the intervention of the Shoalshook Limestone, an omission due to deficiency of calcareous matter or to overlap of the Limestone by the Redhill mudstones, rather than to faulting.

nas. The Shoalshook Limestone which normally occupies a position between the *Dicranograptus*-shales and the Redhill Beds and which, we believe, occurs on a palæontological horizon not lower than the zone of *Pleurograptus linearis*, is not represented in the districts of Camrose and Keeston.

As we have seen that the Redhill Beds do not always lie on the same zone of the *Dicranograptus*-shales, the absence of the limestone may be explained by its overlap by the Redhill mudstones rather than by the thinning-out of the calcareous group.

rill. *Redhill and Slade Beds.*—The Redhill Beds were so named by Messrs. Marr and Roberts from a large quarry at Redhill, north of Haverfordwest. These strata, which consist of blue-grey mudstones, occupy a large area on both sides of the Western Cleddau river to the north of Haverfordwest. They are well exposed at Prendergast paper-mill, and have yielded fossils there and at Redhill quarry and other localities. North of Lambston a fossiliferous sandstone-band makes its appearance in them and persists westward.

The Redhill Beds pass upward into the Slade Beds, which are generally more fossiliferous, more markedly bedded, and present peculiar and characteristic appearances on weathering. The Slade Beds were named by Messrs. Marr and Roberts from exposures at the North Gate at Haverfordwest, where they dip steeply southward from the Redhill Beds.

The fauna of the Redhill and Slade Beds generally resembles that of the Bala Limestone; *Trinucleus seticornis* is present throughout, and in the Slade Beds some decalcified bands are made up chiefly of *Favosites*.

In the neighbourhood of Wiston, only four miles east of Haverfordwest, the beds immediately underlying the Lower Llandovery, and therefore presumably belonging to the Slade stage, depart so markedly from the type in both lithic and faunal characters as to suggest that the Slade Beds have been overlapped by the Lower Llandovery, and that the beds in question should be assigned to the Redhill. However, the discrepancy is possibly due to a change of facies in the Slade Beds themselves.

* Marr and Roberts, *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 481.

Mr. Jones.

The Redhill and Slade rocks occur in a much-faulted area lying to the south and east of Slebech, a mile and a half south of Wiston. As a rule they contain abundance of characteristic fossils. In a small exposure near Little Clerkenhill a thin band of dark-brown rottenstone has yielded many genera of trilobites, including *Chasmops*, though that genus has not hitherto been discovered at this horizon in Britain.*

The base of the Llandovery is only a small distance above them. It is probable, however, that the two series do not succeed one another conformably in this area; in the stream south of Slebech New Church the Llandovery conglomerate is underlain by a considerable thickness of unfossiliferous grey mudstones, and these by abundantly fossiliferous rocks, but near Little Clerkenhill, about a mile to the east, the conglomerate appears to rest almost, if not quite, on the fossiliferous strata.

About a mile to the north begins another area of blue-grey mudstones occupying the position of the Redhill and Slade stage, but here there are no fossils, and the Slade Beds in their typical facies are not recognizable.

Mr. Thom

At Clarbeston Road Station the *Dicranograptus*-shales are succeeded by a low-dipping set of blue-grey mudstones, the boundary between them being normal, but owing to the low dip somewhat irregular in form. The boundary passes in a westerly direction to a point a little south of Lower Haythog Farm, where it runs into the big fault which throws the *Didymograptus-bifidus*-shales and *Tetragraptus*-beds onto the *Dicranograptus*-shales. Emerging from the fault to the north of Withy Hedge, it takes a general south-westerly course to Rudbaxton Church, near which spot the junction between the Redhills and *Dicranograptus*-shales is well displayed, and the upper series is extremely fossiliferous.

From Rudbaxton the boundary keeps a south-westerly direction to Cutty Bridge on the Fishguard Road, and passes on through Knock towards Pelcomb School-house. The Redhills, although not an extremely thick series, occupy an extensive area as a result of a low and constantly changing dip; they are affected by a number of shallow east-and-west folds, anticlines and synclines succeeding each other at frequent intervals along any north-and-south line.

The Camrose anticline has a dome-like form and pitches gently in all directions, but more steeply towards the west; this westerly pitch causes another outcrop of Redhill Beds to occur on the ridge to the west of Camrose village. The blue-grey mudstones occupy the ground around Keeston village, the outcrop narrowing towards Camrose on the east but spreading out towards the west. The beds are almost horizontal, and are surrounded on all sides by *Dicranograptus*-shales, which occupy the valleys and the lower ground.

* J. E. Marr, *Geol. Mag.* for 1907, page 66.

SILURIAN.

rill. *Lower and Middle Llandovery.*—The Lower Llandovery Beds are so well- displayed in the neighbourhood of Haverfordwest that this district is likely to become of special value in the study of the shelly facies of the formation. The Great Western Railway cuttings along the Cartlett valley for three-quarters of a mile above the town, followed by a roadside section along the eastern side of the River Cleddau, extending from the town southward for about a mile, together afford a detailed view of almost all the beds constituting the lower 2,000 ft. of the formation. Of this thickness all except the lowest 500 ft. are abundantly fossiliferous, and specimens from the gasworks and from the Priory Mill are to be found in most collections.

The tracing of the various sandstones and conglomerates has served to reveal the structure of the district, and has rendered it possible for the first time to locate the base of the local Silurian rocks. The conglomerate is singularly impersistent, but its associated blue-black shales are easily identified, and although from lack of exposures they cannot be traced continuously across the country, their base appears to be the only available line of separation between the Llandovery and the Bala.

In the lower part of the formation fossils are scarce; at the junction of the dark shales (1 of the Table on p. 38) with the overlying green mudstones (2), a fossiliferous band near St. Martin's Cemetery, Haverfordwest, has yielded a number of fossils which were described by Mr. F. R. Cowper Reed* as belonging to the Slade Beds of the Bala. Recent stratigraphical work† has proved that this identification of the strata can scarcely be correct, and the recognition of *Diplograptus modestus* by Miss G. L. Elles, in 1907, among Mr. V. M. Turnbull's fossils from the locality, confirms this view. It is, however, due to Mr. Reed to acknowledge that after these results had been brought to his notice he announced‡ a "marked palæontological break between the St. Martin's Mudstone and the Slade Beds proper."

The group of fossiliferous mudstones, about 800 ft. thick, underlying the Gasworks Sandstone is exposed along the roadside between the town and the gasworks, where the sandstone itself forms a low cliff. The beds above the Gasworks Sandstone are poorly exposed on the eastern side of the Cleddau, and a little further south the sandstone with northerly dip is rolled up again at Higgon's Well.

ss. This outcrop crosses the railway-cutting near the Priory Mill, and striking thence across the upper part of Merlin's Hill soon disappears under the Carboniferous rocks. The group of fossiliferous strata underlying the Gasworks Sand-

* *Geol. Mag.* for 1905, pp. 98, 103, 448, 449, 493, 495–497, 499, 500; *ibid.* for 1906, p. 361.

† T. C. Cantrill, *Geol. Mag.* for 1907, p. 537.

‡ *Geol. Mag.* for 1907, p. 536.

stone is exposed for over a quarter of a mile along the river-bank, and is followed to the south by a group of fossiliferous olive-green and buff mudstones, associated with the maroon-coloured beds referred to in last year's SUMMARY OF PROGRESS. Examination of the fossils obtained shows that this is a distinct group from that underlying the Gasworks Sandstone, but as the two are everywhere faulted together their relations can only be deduced from the fossil evidence. This suggests that it occupies a stratigraphical position not far above the Gasworks Sandstone, but whether it is more closely related to the Lower or to the Upper Llandovery remains undecided. The rocks are so well exposed and so fossiliferous in the neighbourhood of Millin that the group might be appropriately named after that locality. A re-examination of part of the Narberth district, in the light of evidence recently obtained near Haverfordwest, has shown the presence of the Millin group along the south side of the Silurian belt from Narberth to the River Cleddau.

*Upper Llandovery.*—As indicated on the Old Series geological map, a strip of Upper Llandovery rocks lies some distance to the south of the Coalfield, and separated from it by a group of igneous rocks of uncertain age. On the south it is usually faulted against Old Red Sandstone, but near Romans Castle Farm the base of the group is in contact with a series of volcanic tuffs and breccias and flows of rhyolite. It consists of a conglomerate with well-rolled pebbles of the underlying volcanic rocks together with some of quartzite, some of the pebbles being three or four inches in diameter though the majority are small.

The conglomerate is succeeded by coarse yellow sandstones, and these by a considerable thickness of yellow mudstones with thin sandstones. Fossils are usually abundant, among which *Pentamerus oblongus* is one of the most characteristic forms.

At Rosemarket the Upper Llandovery sandstone is so full of volcanic material as to be distinguished only with difficulty from a true tuff. To the east of the village rhyolitic breccias appear from underneath the Silurian rocks, but the actual junction is not visible.

Along the northern margin of the Upper Llandovery outcrop soft yellow mudstones are crushed against the plutonic rocks nearly all the way from Langum to beyond Tiers Cross, so as to leave little room for doubt that the junction is mainly a faulted one, but to the east of the Neyland Railway the fault leaves the junction for over a mile and runs in the Upper Llandovery rocks. In this space, therefore, evidence of the relations of the Silurian to the plutonic series may be expected. About a mile south-east of Johnston Station is an old quarry in coarse pebbly sandstone which must lie close to the junction with the dioritic rocks. At the bottom of the quarry some lumps of conglomerate were found much resembling that at Romans Castle in containing well-rolled pebbles

of volcanic rocks, but with large pebbles of diorite in addition. It is probable, therefore, that both the volcanic rocks to the south and the plutonic complex to the north of the Silurian belt are of greater antiquity than the Upper Llandovery of this district.

Mr. Dixon. *Wenlock-Ludlow?*—A group of sandstones and mudstones probably referable to this division has long been known to occur at Freshwater East and Freshwater West, but its exact horizon in the Silurian sequence cannot be determined until the fossils recently obtained have been identified.

### OLD RED SANDSTONE.

Mr. Strahan. In the Lawrenny promontory the Old Red Sandstone dips naturally under Lower Limestone Shales. In the upper part it consists of alternations of red marls with yellow or grey sandstones and coarse grits, but lower down it includes massive grey quartzitic grits and conglomerates with thin green marls, with an occasional cornstone. These strata form a rugged cliff overlooking the Castle Reach of the Daucleddau. They are much folded and faulted, and in places cleaved.

Mr. Jones. The Old Red Sandstone faulted against the Upper Llandovery and other rocks to the west of Langum consists of red marls with some "race" and thin courses of sandstone. The marls are affected by an imperfect cleavage. Some of the sandstones may be described as arkose in view of the large quantity of fresh felspar which they contain.

Along the west bank of the Cleddau south of Langum brown felspathic and chloritic sandstones occur frequently in red marls with "race."

### CARBONIFEROUS.

*Carboniferous Limestone Series.*—To the south of Haverfordwest the Carboniferous rocks are traversed by a succession of shallow folds and strike-faults with a downthrow to the north, and thus cover an extensive area. The base of the limestone-series is exposed in a lane-section about half a mile south of the town. The lower beds consist of muddy sandstones and mudstones with small quartz-grains, and contain traces of plant-remains; they dip off an eroded boss of Silurian mudstones. No limestone occurs in this section, but debris of similar material is met with elsewhere in the district along the lower margin of the limestone-outcrop.

In an old quarry to the west of Merlin's Bridge the section is different; there a thin bed of limestone, crowded with *Seminula*, is associated with calcareous black shales, and overlies several feet of fine-grained white sandstone the base of which is not seen. The rock quarried appears to have been a compact dolomite, but none is now exposed. The limestone has been traced, by means of swallow-holes and subsidence of the ground, as far as Scarrowscant; no evidence has been

obtained of its continuation beyond that locality, the Millstone Grit Series then resting on the Lower Palæozoic rocks.

*Millstone Grit Series.*—The base of the Millstone Grit is seldom visible, but a near approach to it occurs on the south side of the Cresswell River, near Newpark. There the highest visible limestone is followed, after a gap of about 60 ft. in which nothing is visible, by 6 ft. of dark sandy mudstone with a few thin bands of black chert, much resembling the cherts of Bishopston which have yielded radiolaria. Above these lie about 65 ft. of hard grey quartzitic sandstone with an occasional band of small pebbles, and this is followed by about 30 ft. of shale, coarsely concretionary in its upper part. Then comes a band of quartzite about 10 or 15 ft. thick followed by more shale. These strata correspond presumably to the basal grit of the Millstone Grit, and no doubt underlie much of the featureless swampy ground, dotted over with blocks of quartzite, which marks the junction of the limestone and Millstone Grit for miles. Dr. Straha

The other members of the Millstone Grit crop out along the same river from Cresswell Castle westwards. The shales, roughly cleaved, and at times with a large concretionary structure, form the north bank near Tanyard, while some massive sandstones and even-bedded rippled flags appear on both sides of the river nearer Cresswell.

In the district west of the Western Cleddau the Basal Grit consists of only two thin beds of greyish-white quartzite with interbedded black shales, one band of which is crowded with Goniatites; the shales succeeding the higher quartzite bed have also yielded a fairly prolific marine fauna. Near Rosehill, about four miles west of Haverfordwest, the base of the Basal Grit is exposed in a stream where resting on Lower Llandovery mudstones are a few feet of grey shales with small quartz-grains, succeeded by a thin bed of quartzite. It is not known whether in this locality there are two quartzite-beds or only the one exposed in the stream. Though the whole of the Carboniferous Limestone Series has been overstepped and the greater part of the Basal Grit overlapped, yet in spite of these repeated unconformities in the Lower Carboniferous rocks nothing approaching a basement-conglomerate has been met with. Mr. Jone

The Middle Shales preserve their normal characters throughout this tract, but the Farewell Rock has changed considerably, the greater part of it being a conglomerate with streaks of shale and sandstone and an occasional culmy layer. A good section has been recently exposed in a road-cutting near Johnston Mill. Near Freystrop Cross the rock disintegrates into sand, which has been dug for building and other purposes.

The fine-grained quartzite which forms the basal member of the Millstone Grit Series can be traced westward from Haverfordwest; it is exposed in several quarries along the Portfield Road, and forms a ridge overlooking the Llandovery and Bala Mr. Cant

ground on the north. There is evidence that it contains one or more bands of soft black shale. Its base rapidly oversteps various members of the Ordovician and Silurian as it approaches the shores of St. Bride's Bay, near Nolton. It is followed by black shales, forming the Middle or Shale subdivision of the Millstone Grit, which are seldom well-exposed.

Strahan. *Coal Measures.*—The examination of the Coalfield has been continued as far westwards as the Daucleddau. While it is obvious that the measures are thrown into a series of plications ranging west-north-west and are repeated by numerous overthrust-faults following the same general direction, the structure is too complicated and not sufficiently revealed in section to admit of a detailed interpretation. A belt of ground containing repeated outcrops of the Timber Vein series, the newest strata recognised in Pembrokeshire, extends from Saundersfoot to beyond Jeffreston, as described in the SUMMARY OF PROGRESS for 1905, p. 57. It appears to be defined by a series of large overthrusts on both sides. One of those on its southern side cuts the coast 480 yards south of Saundersfoot Harbour, where it displays itself as an undulating but nearly horizontal fracture, gently rising towards the north, and evidently an overthrust from the south. Though neither this, nor any of the other thrust-faults visible in this cliff, can be precisely located inland, the general line of thrusting appears to be indicated by a swampy tract which runs south of Wooden, Cold Inn and Jeffreston, and which limits on the south all but one of the outcrops of Timber Vein referred to. The fault or thrust to the north of the belt is assumed to be a continuation of a large northerly downthrow proved at Treberth and Erroxhill, but in this case also it is more probable that the disturbance consists of a number of thrusts arranged more or less along one line, than of a single continuous fracture. About a mile west of Jeffreston the belt of Timber Vein outcrops lying between these two lines of disturbance comes to an end.

The measures to the south of it are believed to belong to the lower part of the Coal-measures. In one place only, at Norchard Mountain, the Timber Vein has been "patched"; elsewhere, thin seams have been worked for short distances along isolated outcrops. None are being worked now, nor do any appear to have been of much value. These remarks apply to the neighbourhood of East Williamston and Redberth, and in view of the fact that the outcrops occupy a position relatively to the Timber Vein belt, similar to that held by the Stammers Veins, it is reasonable to suggest that they correspond to those veins.

At Marketgate, near Cresselly, the workings were more continuous, and one vein at least appears to have been of better quality. The Jeffreston Mountain Vein, as it was called, crops out at Lanesend. Southwards, with a vein 8 inches thick 42 yards above it, it was worked at small depths near Marketgate. The dip in these workings was at a gentle

angle eastwards. The measures, however, plunged down nearly vertically towards the north-east along a line running from Lanesend towards Bromley Wells, and the vein was followed no farther. This steep dip appears to be the northern limb of a syncline which is visible at Beacon Hill. In the north rise of the syncline three veins crop out, one of which passes under Longpark, but it is not certain whether any of these correspond to the Marketgate Veins.

This tract was drained by an adit which opens on to the river at Cresswell Quay, and which passed by the "Fore" or "Ford" Pit. That pit was levelled some years ago, but appears to have been situated about 200 yards south-east of Cresselly Green School. In its course to the pit the adit traversed ground which is dotted over with old pits, with an occasional trench marking the site of an open crop-working. No written records exist of the coals worked here, but it is reported that the adit started in the "Rye-grass" Vein in the Treen Dingle, that from the "Rye-grass" Vein it was carried, by drifting south, into the "New Back" Vein. In that vein it was taken to the Fore Pit, and by a drift thence into the Jeffreston Mountain Vein. The "Rye-grass" Vein which was the lowest, was about 13 or 14 inches thick, the "New Back" Vein about 24 to 30 inches thick, and the Mountain Vein, or highest, about 18 or 20 inches thick. It was presumably the "Rye-grass" which was worked near Freestone Hall, and at Landigwinnet, near Redberth. It seems likely that these veins may correspond to the Lower Level and underlying veins. One that was worked at Brince was known as the Rock Vein, and the same name was applied to a thin seam about half a mile west of East Williamston. But the name is common and no correlation with the Rock Vein of Moreton can be made on the strength of it.

*Igneous Rocks.*—A series of lavas, tuffs, breccias and agglomerates, of andesitic and possibly trachytic character, was met with in the Spittal Tunnel and in the north tunnel-heading on the eastern side of the Cleddau. The outcrop, which is not continuous, may be traced across the river to Wolfsdale, New Inn, and Dudwell. On the north, these igneous rocks are bounded by a line of fault which brings *Lingula*-flags into contact with them. Their southern junction, with the *Tetragraptus*-beds, seems to be a fault at most places where it can be observed; at the same time there does not seem to be so big a break between the igneous rocks and the *Tetragraptus*-beds as between them and the *Lingula*-flags.

We are not at present able to make any definite statement as to the age of this volcanic series, but certain evidence recently collected causes us to doubt their belonging to a pre-Cambrian age, as originally surmised.

On the Old Series map the rocks of the Johnston ridge south of Haverfordwest were separated into syenites and greenstones, passing into one another near Johnston. A variety of rock-types is represented, but the greater part of the mass is a

dark-grey medium-grained dioritic rock usually containing some quartz; the acid modifications are usually coarser-grained. The whole mass is traversed by a large number of fine-grained diorite dykes; compact and almost amorphous at the edges. These appear to represent a late phase of intrusion; none of them has been observed to penetrate the sedimentary series in contact with the igneous mass.

Two areas of volcanic rocks have been met with. In a lane leading down to Romans Castle Farm a series of rhyolites, tuffs and breccias are exposed; the rhyolites were distinguished on the Old Series one-inch map, but the fragmental rocks, which are predominantly of green and purple colours, were included with the Old Red Sandstone. On the north side the Upper Llandovery with a conglomerate rests on rhyolites, while on the south side the Old Red Sandstone is faulted against tuffs and breccias.

Another area of similar rocks about a mile to the south-east of Tiers Cross was not represented on previous maps. There are no exposures of solid rock, but there is abundant debris in the hedge-banks. Numerous loose blocks with pebbles of volcanic rocks point to the presence of a strong conglomerate at the base of the Upper Llandovery.

## GLACIAL.

Gravels, similar to those described from the districts of Castelldwyran, Llanfallteg and Clynderwen, cap almost all hills which have an elevation of more than 100 and less than 200 ft., very few occurring below the 100 ft. or above the 200 ft. contour. The valleys are practically free from glacial drift of any description, and are usually excavated in the solid rock. All the glacial deposits of the districts north of Haverfordwest, such as Rudbaxton, Camrose and Keeston, are gravels and sand, containing occasional flint-pebbles and other rocks which do not occur in place in the area surveyed.

Scattered over the surface of the lower ground are large boulders often ranging up to as much as 10 ft. in greatest dimensions. These erratics belong to two chief types, namely rhyolite and hornblende-porphyrite. From their size and abundance it is safe to assume that their source lay somewhere in Pembrokeshire; the rhyolites have probably been derived from the rhyolitic masses of Trefgarn, Plumstone, Cuffern and Roch, but the hornblende-porphyrite, although a rock of well-marked characters, has not as yet been traced to its source.

Amongst other rocks occurring as boulders are diorite, ophitic diabase, conglomerates and purple and green tuffs, not all of which have been found in place within the district as yet mapped.

Patches of sand and gravel occupy low plains between the minor valleys on both sides of the River Cleddau, near Haver-

fordwest. The surface on which they rest seldom attains an elevation of more than 120 ft. above the level of the river, and nearer the river itself the surface falls to within 50 ft. of it. These deposits appear to be related to the Cleddau valley, though some post-glacial erosion of the gravel must have since taken place, as most of the minor streams cut through it into the "solid" rocks below.

A tract of yellow boulder-clay largely derived from the Upper Carboniferous of Nolton and Simpson to the north-west occupies a low area traversed by Knock Brook, a tributary of the Cleddau. Along the stream it passes into gravel in which a few chalk-flints are present. The constitution of this drift suggest a derivation from the north-west by ice which moved in from St. Bride's Bay.

Numbers of isolated boulders ranging up to 10 ft. in diameter lie scattered over the districts otherwise devoid of drift; in the neighbourhood of Haverfordwest they indicate a derivation from the north-north-west and north-west.

Small areas of Boulder Clay with boulders from distant M sources occur on the Carboniferous rocks south-west of Haverfordwest, while a larger area lies on the igneous and Upper Llandovery rocks south of The Troopers Inn. A small patch of gravel has been observed along the railway-cutting south of Johnston Station, and another about a quarter of a mile to the east. Glacially transported boulders of considerable size are generally distributed over the whole of the area examined.

## FAULTS AND DISTURBANCES.

Near and north of Haverfordwest the beds are thrown into M a series of sharp east-and-west folds which the mapping of the sandstones in the Lower Llandovery has brought out with M great clearness. Occasional strike-faults are encountered which appear to be overthrusts from the north, as in the case of the faulting at Shoalshook (p. 41). That this folding was largely pre-Carboniferous in age is rendered evident by the manner in which the Carboniferous base oversteps various members of the Ordovician and Silurian; but the Carboniferous rocks themselves have been subjected to some folding, having approximately the same strike though much less intensity.

As the Carboniferous base is traced north-westward from M Haverfordwest toward Nolton, on St. Bride's Bay, a marked overlap within those rocks reveals itself; for at Haverfordwest a thin bed of limestone is visible below the Millstone Grit (p. 46) and a little westward, though the limestone is no longer visible, its former presence is suggested by some signs of subsidence. At Nolton Cross, however, only four or five miles farther west, not only is there no evidence of the limestone ever having been deposited, but the Basal Grit itself is overlapped by the overlying Middle or Shale subdivision.

This overlap, clear though it is, is not marked by any littoral conditions, so that it is probable that the land bordering the Carboniferous waters was low-lying, as one would expect from the soft nature of the rocks of the district.

Jones. The Upper Bala and Llandovery Rocks in the neighbourhood of Slebech New Church are thrown into a succession of sharp anticlines and synclines with a westerly pitch, whereby the outcrops zig-zag across the normal strike of the country for about two miles; several important strike-faults also occur. The structure is similar to that previously referred to in the district north of Narberth. In the neighbourhood of Haverfordwest the Carboniferous rocks are affected in a like manner, and there is evidence of repeated but reversed movement along the same lines of disturbance, for whereas in the Silurian tract the faults are downthrows to the south, in the Carboniferous rocks there are downthrows to the north along the same lines. By repeated overthrusting the lower part of the Millstone Grit Series occupies a belt of country nearly a mile wide to the south of Haverfordwest, in spite of a persistent southerly dip.

Along the south margin of the coalfield the igneous rocks of the "Johnston ridge" are faulted against the Carboniferous rocks; the undulating nature of the boundary suggests that the fault is a thrust of low inclination and is probably a continuation of the powerful disturbance near Langum Ferry previously described. The boundary of the Upper Llandovery and the Johnston dioritic rocks is also a strike-fault along the greater part of its course. Immediately to the south of Johnston Church a lenticle of pulverized mudstones is included between two tracts of igneous rocks. So far as examined the Old Red Sandstone west of Langum is faulted along the whole of its northern boundary against Upper Llandovery and volcanic rocks, and for a short distance against the Johnston diorites.

The softer beds of the Old Red Sandstone are persistently affected by a well-marked cleavage-structure which dips steeply to the south, and in the absence of sandstones it is extremely difficult to determine the directions of the bedding-planes.

## ECONOMIC.

rious. The Redhill mudstones have been quarried at Redhill quarry, north of Haverfordwest, and the Shoalshook Limestone is used for bridge-building by the Great Western Railway Company. A fine-grained grey sandstone from near the base of the Lower Llandovery has been used for building and roadstone at several places; it weathers brown or yellow.

The andesitic series of Trefgarn and Wolfsdale and the Johnston igneous rocks are much used for road-metal in their respective districts. The basal quartzite of the Millstone Grit Series near Haverfordwest, and the Carboniferous Limestone

near Pembroke are used for the same purpose. The latter was at one time quarried for Government buildings and also burnt for lime, but only one kiln is now in use.

The Johnston igneous rocks have locally weathered to a considerable depth and are then dug for "sand" for building and other purposes. Under certain circumstances the Farewell Rock becomes disintegrated into sand.

The water-supply of Haverfordwest is derived from a well sunk in the alluvial gravel by the side of the Cleddau, about a mile above the town.

Copious springs issue along the margins of the Johnston igneous rocks, and one is utilised by a mineral water factory, at Bullford.

The old adit described on p. 49 is used as a source of water for Cresselly and Cresswell.

## II.—PETROGRAPHICAL WORK.

Dr. Flett

Dr. Flett reports that during the year he has been engaged principally in preparing, revising, and editing the petrographical chapters required for forthcoming memoirs, *e.g.*, Midlothian, Kilmartin, Glen Tilt, the Lizard. The Land's End and Plymouth memoirs have been corrected for the press and are now issued. The Oban memoir will shortly be published, and the others mentioned above are, with the exception of the Lizard memoir, ready to go to the printer.

## III.—CHEMICAL WORK.

Dr. Pol

Dr. Pollard has been engaged during the year 1907 principally in the preparation of the memoir on the coals of the South Wales district, which is now passing through the press. Consequently, nearly all the analytical work has been done by Mr. E. G. Radley, under Dr. Pollard's supervision. Only the more important analyses are quoted in this report; fuller particulars of the mode of occurrence and mineral composition of the rocks will be given in the corresponding memoirs which will shortly be published.

*Analyses for Dr. Flett. Carboniferous intrusive rocks from Midlothian and West Lothian. (Sheet 32.) Midlothian Memoir.*

11390. *Essexite.* Intrusive sill, Lochend, near Edinburgh.

This is a rather finely crystalline rock, resembling a diabase in appearance and believed to belong to the same series as the teschenites and picrites of this area. Its special feature is the abundance of plagioclase rich in alkalies (oligoclase), with brownish augite. The rock contains little analcite, and if olivine was present it occurred only in small amount. The chemical composition is that of the essexites.

13437. *Teschenite,* Whitehouse Point, Dalmeny, near Edinburgh.

This is an exceptionally good example of the teschenites of Midlothian. It is rich in analcite and brown hornblende; plagioclase and augite are also abundant and the olivine has weathered into serpentine.

11894. *Teschenite,* Wester Ochiltree, 2½ miles S.E. of Linlithgow.

This rock is finer grained than the preceding one and contains less analcite, but consists of the same minerals. The two rocks are very closely similar in composition.

(For other analyses of rocks of this group see SUMMARY OF PROGRESS for 1905, pp. 74 and 75, Nos. 11,859, 11,860, 11,897.)

| Slice No. | 11390. | 13437. | 11894. |
|---|---|---|---|
| $SiO_2$ | 48·63 | 46·06 | 43·55 |
| $TiO_2$ | 2·04 | 2·56 | 2·48 |
| $Al_2O_3$ | 15·03 | 15·94 | 14·84 |
| $Fe_2O_3$ | ·51 | 2·94 | 3·09 |
| FeO | 9·55 | 7·44 | 7·44 |
| MnO | ·20 | ·31 | ·23 |
| (CoNi)O | nt. fd. | nt. fd. | nt. fd. |
| BaO | ·04 | ·10 | ·07 |
| SrO | undet. | nt. fd. | nt. fd. |
| CaO | 5·95 | 7·04 | 7·66 |
| MgO | 6·34 | 4·14 | 7·41 |
| $K_2O$ | ·56 | 2·76 | 1·90 |
| $Na_2O$ | 5·32 | 4·95 | 3·82 |
| $Li_2O$ | trace | ? trace | trace |
| $H_2O$ at 105° C. | ·93 | ·55 | 1·79 |
| $H_2O$ above 105° C. | 3·16 | 4·22 | 5·08 |
| $P_2O_5$ | ·34 | ·84 | ·63 |
| $FeS_2$ | ·44 | ·36 | ·13 |
| $CO_2$ | 1·12 | ·11 | ·53 |
| Cl | — | trace | nt. fd. |
| Total | 100·16 | 100·32 | 100·65 |

(Anal. E. G. Radley).

*Analyses for Mr. E. B. Bailey. Carboniferous volcanic rocks from the Glasgow district. (Prepared for the Memoir on the Glasgow district.)*

13303. Small intrusion into ash of neck, Little Galdon neck, N. of Kilpatrick Hills (Sheet 30), *Olivine basalt* of the Jedburgh type, very fresh.

13311. *Essexite.* Irregular dyke of great thickness intruded into the Campsie lavas, Hillside 300 yards N. of Craw, Road to Fintry, 1 mile N. of Lennoxtown (Sheet 31). (Compare analysis 11390, given above.)

13314. Sill, Old Quarry, Barshaw House, 1½ miles E. of Paisley. Probably a *theralite* but much decomposed.

| Slice No. | 13303. | 13311. | 13314. |
|---|---|---|---|
| $SiO_2$ | 46·45 | 45·03 | 40·87 |
| $TiO_2$ | 3·11 | 2·30 | 2·85 |
| $Al_2O_3$ | 16·08 | 14·82 | 16·23 |
| $Fe_2O_3$ | 3·94 | 2·77 | 1·31 |
| FeO | 8·57 | 8·81 | 7·37 |
| MnO | ·48 | ·37 | ·64 |
| (CoNi)O | nt. fd. | ·05 | ·06 |
| BaO | nt. fd. | nt. fd. | nt. fd. |
| CaO | 7·64 | 9·83 | 11·13 |
| MgO | 5·94 | 7·79 | 9·83 |
| $K_2O$ | 1·43 | 1·51 | ·53 |
| $Na_2O$ | 3·50 | 4·33 | 2·78 |
| $Li_2O$ | ? trace | ? trace | ? trace |
| $H_2O$ at 105° C. | ·24 | ·24 | 1·35 |
| $H_2O$ above 105° C. | 1·68 | 1·71 | 4·28 |
| $P_2O_5$ | ·51 | ·58 | ·52 |
| $FeS_2$ | trace | ·15 | ·21 |
| $Fe_7S_8$ | ·06 | nt. fd. | nt. fd. |
| $CO_2$ | ·41 | ·22 | ·38 |
| Total | 100·94 | 100·51 | 100·34 |

(Anal. E. G. Radley).

*Analyses of rocks for Mr. E. B. Bailey. Carboniferous volcanic rocks from the Glasgow area. (Prepared for the Memoir on the Glasgow district.)*

13310. Laccolite, Roadside, Newton o'Fintry (Sheet 30). *Phonolite* with nepheline fairly abundant and in large measure fresh. The ferromagnesian minerals include ægirine-augite and barkevicite.

13354. Lava, 1,550 feet S. 30° W. of the Cairn on Lairs, 1½ miles N. of Lennoxtown, *Mugearite* decomposed. (Compare analysis 12710 in Summary of Prog. for 1906, p. 70, and 8732 in *Mem. Geol. Survey*, Tertiary Igneous Rocks of Skye (1904) p. 263).

13345. 2,100 feet S.S.E. of the cairn on Cairn on Lairs, 1½ miles N. of Lennoxtown. This rock is allied to the *Keratophyres* but is much decomposed.

*Analyses for Dr. Flett. Tertiary dykes of Ardmucknish, Argyllshire. (Memoir on Sheet 45, the Oban and Dalmally district.)*

13191. Dyke of *monchiquite* containing phenocrysts of anorthoclase, West side of Camas an Fhais, ½ mile N.E. of Rudha Fionn Aird, Argyllshire.

| Slice No. | 13310. | 13354. | 13345. | 13191a. |
|---|---|---|---|---|
| $SiO_2$ | 57·98 | 50·29 | 69·48 | 43·55 |
| $TiO_2$ | ·20 | 1·67 | ·14 | 2·52 |
| $Al_2O_3$ | 17·92 | 18·11 | 11·99 | 14·60 |
| $Fe_2O_3$ | 4·23 | 4·09 | 2·54 | 5·34 |
| FeO | 2·72 | 8·06 | 2·46 | 7·46 |
| MnO | ·21 | ·65 | ·20 | ·55 |
| (CoNi)O | nt. fd. | nt. fd. | ·03 | ·05 |
| BaO | nt. fd. | nt. fd. | nt. fd. | ·27 |
| SrO | nt. fd. | nt. fd. | nt. fd. | nt. fd. |
| CaO | 2·12 | 1·70 | 1·72 | 7·94 |
| MgO | ·34 | 3·32 | 1·16 | 4·77 |
| $K_2O$ | 5·24 | 2·65 | 4·01 | 1·40 |
| $Na_2O$ | 6·99 | 5·06 | 3·33 | 5·01 |
| $Li_2O$ | ? trace | ? trace | trace | trace |
| $H_2O$ at 105° C. | ·64 | ·86 | ·32 | ·63 |
| $H_2O$ above 105° C. | 1·76 | 3·45 | 1·56 | 4·58 |
| $P_2O_5$ | ·08 | ·44 | ·08 | ·88 |
| $FeS_2$ | nt. fd. | ·06 | ·05 | ·31 |
| $CO_2$ | nt. fd. | nt. fd. | 1·34 | ·56 |
| Total | 100·43 | 100·41 | 100·41 | 100·42 |

(Anal. E. G. Radley).

13191a. *Anorthoclase felspar* phenocrysts of dyke of monchiquite. (13191). The crushed felspar was first treated with hydrochloric acid (dil.) to get rid of carbonates, then separated with boro-tungstate. The sp. gr. of the analysis sample (pyknometer) was 2·608 (calc. to water at 4°).

Slice No. I3191b.

| | | mol. rats. | |
|---|---|---|---|
| $SiO_2$ | 65·83 | 1·0898 | |
| $Al_2O_3$ | 19·97 | ·1954 | |
| $Fe_2O_3$ | ·75 | ·0047 | |
| BaO | ·53 | ·00345 | ·01015 |
| SrO | ·29 | ·0028 | |
| CaO | ·22 | ·0039 | |
| MgO | ·05 | ·0012 | |
| $K_2O$ | 3·10 | ·03287 | |
| $Na_2O$ | 8·70 | ·1401 | |
| $H_2O$ 105° C. | ·07 | — | |
| $H_2O$ above 105° C. | ·18 | ·0099 | |
| Total | 99·69 | | |

(Anal. W. Pollard).

Traces of $TiO_2$ and MnO.

Calculating the various felspars possibly represented, the following figures are obtained:—

| | |
|---|---|
| $(BaSrCa)O\ Al_2O_3\ 2SiO_2$ ... ... ... | 3·31 |
| $K_2O\ Al_2O_3\ 6SiO_2$ ... ... ... ... | 18·38 |
| $Na_2O\ Al_2O_3\ 6SiO_2$ ... ... ... ... | 73·80 |

## *Analyses of Highland schists and gneisses for Mr. C. T. Clough, Mr. E. M. Anderson, and Dr. Flett.*

12610. *Biotite kyanite gneiss*, in Lewisian gneiss series, 1,050 yards E.S.E. of Balvraid, Inverness (Sheet 71).

13251. *Granulitic biotite gneiss*, in Lewisian gneiss series, 120 yards E.S.E. of Eilean a Chlamhuinn, Inverness (Sheet 71).

13209. *Epidotic biotite gneiss*, Allt Garbh Choire, just above junction with third lowest tributary, Inverness (Sheet 82).

11800. *Chloritic Schist*, in the upper thrust plane on the Abhuinn Salachie, 1 mile S.E. of Glen Calvie Lodge, Strathcarron, Ross-shire (Sheet 93).

These rocks were analysed to see if it could be determined from their chemical composition whether they were sedimentary or igneous gneisses. 12610 has the characters of an argillaceous sediment; 13251 resembles certain granitites in composition; 13209 is somewhat abnormal and the analysis does not throw much light on its origin; 11800 is evidently a lamprophyre sill (probably an olivine minette).

| Slice No. | 12610. | 13251. | 13209. | 11800. |
|---|---|---|---|---|
| $SiO_2$ | 55·82 | 70·45 | 59·98 | 50·76 |
| $TiO_2$ | 1·10 | ·43 | 1·72 | ·76 |
| $Al_2O_3$ | 18·91 | 14·86 | 14·39 | 12·30 |
| $Fe_2O_3$ | 1·80 | 1·34 | 5·10 | 1·19 |
| FeO | 8·43 | 1·46 | 4·72 | 6·65 |
| MnO | ·21 | ·23 | ·45 | ·30 |
| (CoNi)O | ·04 | ·04 | ·02 | ·06 |
| BaO | nt. fd. | nt. fd. | nt. fd. | ·04 |
| SrO | — | — | nt. fd. | — |
| CaO | 2·23 | 3·18 | 4·72 | 6·26 |
| MgO | 5·38 | 1·47 | 2·21 | 11·75 |
| $K_2O$ | 2·48 | 1·10 | 2·20 | 4·79 |
| $Na_2O$ | 1·22 | 4·92 | 2·95 | 2·16 |
| $Li_2O$ | trace | trace | ? trace | trace |
| $H_2O$ 105° C. | ·19 | ·04 | ·07 | ·22 |
| $H_2O$ above 105° C. | 1·66 | ·49 | 1·02 | ·66 |
| $P_2O_5$ | ·09 | ·11 | ·48 | ·28 |
| $FeS_2$ | trace | trace | ·24 | ·18 |
| $CO_2$ | — | — | nt. fd. | 1·39 |
| $V_2O_3$ | — | — | — | ·03 |
| $Cr_2O_3$ | — | — | — | ·10 |
| Cl | trace | — | — | nt. fd. |
| Total | 99·56 | 100·12 | 100·27 | 99·78 |

(Anal. E. G. Radley).

*Analyses for Dr. Flett. Pillow-lavas and hornblendic schists from Cornwall and from Scotland.*

E 5791. *Spilite* or Pillow-lava, of Veryan series, Tregidden, 2½ miles W.N.W. of St. Keverne, Cornwall (Sheet 359). Compare with E 4947, Summary of Progress for 1906, p. 69.

E 5797. *Hornblende Schist*, of Lizard series, Quarry at Lower Relowas, nearly 1 mile S.W. of St. Martin, Cornwall (Sheet 359).

S 13040. *Sheared Spilite*, passing into chlorite hornblende schist, ⅗ mile E.S.E. of Ardifuir, N. side of Crinan Loch, Argyllshire (Sheet 36). Compare with E 5791 above.

S 13041. *Sheared dolerite* of same series, hill-top on N.E. side of Ardifuir, N. side of Crinan Loch, Argyllshire (Sheet 36).

| Slice No. | E. 5791. | E. 5797. | 13040. | 13041. |
|---|---|---|---|---|
| $SiO_2$ | 47·56 | 48·64 | 49·74 | 42·36 |
| $TiO_2$ | 2·40 | 1·90 | 2·05 | 4·95 |
| $Al_2O_3$ | 14·27 | 14·99 | 14·85 | 14·09 |
| $Fe_2O_3$ | 1·63 | 3·42 | 1·04 | 2·17 |
| FeO | 6·80 | 7·76 | 10·61 | 10·48 |
| MnO | ·30 | ·30 | ·39 | ·28 |
| (CoNi)O | ·08 | nt. fd. | nt. fd. | ·09 |
| BaO | nt. fd. | nt. fd. | nt. fd. | nt. fd. |
| CaO | 10·95 | 9·60 | 6·17 | 10·05 |
| MgO | 4·90 | 7·76 | 2·48 | 5·70 |
| $K_2O$ | ·27 | ·52 | ·53 | ·80 |
| $Na_2O$ | 4·61 | 3·52 | 4·52 | 3·26 |
| $Li_2O$ | ? trace | trace | ? trace | trace |
| $H_2O$ 105° C | ·42 | ·10 | ·05 | ·12 |
| $H_2O$ above 105° C. | 2·65 | 1·25 | 3·37 | 2·92 |
| $P_2O_5$ | ·19 | ·16 | ·62 | 1·02 |
| $FeS_2$ | ·22 | ·06 | ·13 | nt. fd. |
| $Fe_7S_8$ | ·05 | — | — | — |
| $CO_2$ | 2·95 | ·23 | 3·18 | 1·73 |
| Cl | — | — | trace | trace |
| Total | 100·25 | 100·21 | 99·73 | 100·02 |

(Anal. E. G. Radley.)

## IV.—PALÆONTOLOGICAL WORK.

Upwards of 9,000 specimens have been collected during the year in connection with the current survey work. Materials of this kind have been dealt with principally by Dr. Ivor Thomas, but suites of fossils have also been submitted to the following specialists, who are not members of the staff: Dr. Wheelton Hind, Dr. R. Kidston, Mr. P. Lake, Dr. C. A. Matley, Mrs. Shakespear and Dr. R. H. Traquair. Mr. E. A. N. Arber completed his revision of the collection of coal-plants in the museum. Dr. Kidston has examined a series of plant remains from the Coal measures of Anglesey, the property of Mr. T. Prichard, which were made available for study through

the good offices of Mr. E. Greenly. They were collected many years ago, and are in a much fresher condition of preservation than any similar specimens which can now be obtained from that district.

A complete list of the donations to the museum is published in the Annual Report for the year 1907. The most important additions by gift to the palæontological collections are a series of Mollusca from the Kimeridge and Speeton Beds of Speeton, Yorkshire, presented by Mr. C. G. Danford, and a set of Ordovician fossils from Haverfordwest, presented by Mr. V. M. Turnbull. The principal purchase of the year was a series of mammalian bones, chiefly from the Pliocene Beds of Norfolk and Suffolk. These include a femur of *Elephas meridionalis* Nesti, from the Forest Bed of Overstrand, Norfolk, figured by Leith Adams (Mon. Brit. Foss. Elephants; Palæontographical Society, 1881, p. 223, pl. xxvi., figs. 3, 3a, 3b). This specimen measures no less than 49¾ inches in length, and in the opinion of Dr. Leith Adams, belonged to an animal fourteen feet high at the shoulder. The purchase also included a series of Mammalia, partly of Pliocene age, which were dredged from the bed of the North Sea.

During the year, the work of the palæontological staff has consisted principally in dealing with the materials collected for current survey purposes, and in coping with the increasing pressure of routine work. It is unnecessary to enumerate in detail the sources from which the varied collections have been obtained in direct connection with the survey work, and the results of the examination of these materials will be set forth in their appropriate places in the sheet memoirs. In the course of the work of this character no points of special scientific interest have arisen which seem to call for particular notice in this report. It may be mentioned that Mr. J. Pringle paid a visit to the neighbourhood of Pont Erwyd, in Cardiganshire, with the view of obtaining well-preserved fossils, principally of Llandovery age, for the enrichment of the museum collection, and his search proved very successful.

In the museum, Mr. Allen completed a manuscript catalogue of the Tertiary Vertebrata, and all these specimens have now been mounted and arranged. The Lamellibranchiata of the Carboniferous Limestone have also been arranged and catalogued, and the majority of the figured specimens have been noted in preparation for a future instalment of Mr. Allen's catalogue of types and figured specimens. A further section of this catalogue will be completed for publication as soon as the pressure of other important duties becomes less insistent. Mr. Allen has also arranged a case in the museum for the exhibition of a series of Mullusca from the Speeton Beds, and a suite of specimens to illustrate the zonal palæontology of the Carboniferous Limestone, in accordance with Dr. A. Vaughan's scheme. The work of registering specimens in the museum has been satisfactorily advanced, and in addition to employment in this task, Mr. S. W. Morgan has carried

out a considerable amount of revision in the labelling of specimens in the museum cases, particularly amongst the Graptolites, Carboniferous Lamellibranchs, plants from the Coal-measures. and Cretaceous Lamellibranchs.

The following specimens in the Museum have been described or figured and described during the year:—

## In the Palæontographical Society's Volume for the Year 1907.

### *Cretaceous Lamellibranchia*, Vol. II. Part 4.

By Mr. H. Woods, M.A.

Cyprina (Venilicardia) protensa *sp. nov.*, pl. xxi., f. 5, p. 137.
„ ( „ ) angulata *J. Sow.*, text-figure 23, p. 142.
Lucina downesi *sp. nov.*, pl. xxiv., f. 15, p. 155.
„ ? sculpta *Phill.*, pl. xxiv., f. 7, p. 153.
„ sp., pl. xxiv., f. 4, p. 152.
Mactra angulata *J. de C. Sow.*, pl. xxvii., figs. 19, 23, p. 177.
Sphaera corrugata *J. Sow.*, text-figure 26, p. 159.
„ sp., pl. xxv., f. 3, p. 159.
Thetironia laevigata (*J. Sow.*), pl. xxvi., figs. 11, 13, p. 169.
Unicardium ringmeriense (*Mant.*), pl. xxv., f. 14, p. 164.

### *British Conulariæ.*

By Miss I. L. Slater, B.A.

Conularia corium *Salt.*, p. 15.
„ crassa *sp. nov.*, pl. iv., f. 5, p. 32.
„ elongata *Portl.*, p. 31.
„ globosa *sp. nov.*, pl. iii., figs. 7*a-d*, 8, p. 27.
„ laevigata *Salt.*, p. 17,
„ microscopica *sp. nov.*, pl. ii., f. 6, p. 24.
„ quadrisulcata *J. Sow.*, pl. iii., f. 4*a*, *b*, p. 25.
„ sowerbyi *de Vern.*, pl. v., fig. 8, p. 37.
„ subtilis *Salt.*, pl. iv., f. 9*a*, *b*, p. 33.
„ vesicularis *sp. nov.*, pl. v., f. 3, p. 36.
„ sp. (? C. margaritifera *Salt.*), p. 24.

## In the Proceedings of the Yorkshire Geological Society. Vol. XVI. Part 1.

### *Notes on the Speeton Ammonites.*

By Mr. C. G. Danford.

Acantoceras ? peltoceroides *Pavlow*, pl. xiv., f. 5.
? Desmoceras *cf.* cassidoides (*Uhl.*), pl. xiv., f. 6.
Hoplites amblygonius *Neum. & Uhl.*, pl. xiii., f. 4.
„ deshayesi (*Leym.*), pl. xiv., f. 3.
„ euthymi (*Pictet*), pl. xiii., f. 8.
„ hystrix (*Phill.*), pl. xiii., f. 7.
„ oxygonius *Neum. & Uhl.*, pl. xiii., f. 3.
„ regalis (Bean) *Pavlow*, pl. xiii., f. 2.
„ roubaudi *d'Orb.*, pl. xiii., f. 1.
„ spp., pl. xiii., f. 5, 6; pl. xiv., f. 1.
„ ? heteroptychus *Pavlow*, pl. xiv., f. 2.

Olcostephanus (Astieria) astieri (*Sharpe*), pl. xi., f. 7.
„ ( „ ) spitiensis (*Blanf.*), pl. xi., f. 6.
„ ( „ ) sulcosus *Pavlow*, pl. xi., f. 8.
„ (Craspedites) fragilis (*Traut.*), pl. xi., f. 1.
„ (Polyptychites) beani *Pavlow*, pl. xi., f. 5.
„ ( „ ) *aff.* beani, pl. xi., figs. 2, 4.
„ ( „ ) bidichotomus (*Leym.*), pl. x., f. 1.
„ ( „ ) *cf.* keyserlingi *Neum. & Uhl.*, pl. x., f. 3.
„ ( „ ) polyptychus (*Keyserl.*), pl. x., f. 2.
„ „ ) ramulicosta *Pavlow*, pl. xi., f. 3.
„ (Simbirskites) concinnus (*Phill.*), pl. xii., f. 2.
„ ( „ ) decheni (*Roemer*), pl. xii., f. 7.
„ ( „ ) discofalcatus (*Lahusen*), pl. xii., f. 8.
„ ( „ ) payeri (*Toula*), pl., xii., f. 1.
„ ( „ ) progrediens (*Lahusen*), pl. xii., f. 5.
„ ( „ ) subinversus *M. Pavlow*, pl. xii., f. 4
„ ( „ ) umbonatus (*Lahusen*), pl. xii., f. 6.
„ ( „ ? ) sp., pl. xii., f. 3.
Oppelia nisoides *Sarasin*, pl. xiv., f. 7.
Perisphinctes lacertosus (*Dum. & Font.*), pl. xiv., f. 4.

## V.—MUSEUM OF PRACTICAL GEOLOGY.

Mr. Howe.

The principal alteration effected in the Museum has been the extension of the exhibition space on the ground floor by the removal of the framework from two of the arches, thereby opening out a large area over the site of the old lecture theatre.

In this space the three large models, viz., those of the London Basin, the Isle of Purbeck, and the Assynt district, have been placed in juxtaposition where they form a series representing three stages of geological complexity, and in this position it is hoped they will prove convenient for teaching purposes. A number of photographic enlargements have been displayed near the Assynt model to illustrate the scenery and geology of the district, and samples of the rocks from the same region may be examined in the case by the side of the model.

Continuing the scheme for illustrating new Memoirs and maps, by a collection of rocks, fossils and photographs of the district, the following exhibits have been arranged, with the co-operation of the field staff, viz., Newquay, Sheet 346; Falmouth, Sheet 352; Ammanford, Sheet 230; West Gower, Sheet 246; and Swansea, Sheet 247. These exhibits will be replaced by others as new Memoirs are issued.

# II.—SCOTLAND.

## I.—FIELD-WORK.

Horne.

The ground surveyed in the Highlands was arranged in two districts as follows;—

1. West Highland district, including the area between Glencoe and Ben Nevis, with Colonsay and part of Mull, under Mr. Clough, M.A.

2. North Highland district, containing parts of the counties of Inverness and Caithness, under Mr. Hinxman, B.A.

In the West Highland district further progress was made with the mapping of the mountainous ground between Glencoe and the northern margin of Sheet 53, and when the deer forest ground was not available field-work was continued in Colonsay, Mull, and Lismore. Sheet 35 was finished.

In the North Highland district, the unsurveyed areas in the basins of the Findhorn, the Dulnan, the Spey and the Nairn were mapped (Sheet 74), and that sheet is now completed. Field-work was also continued in Sheets 109 and 110 in the county of Caithness.

The revision of all the ground included in the Glasgow district map is now completed, and attention was further directed to the revision of the Carboniferous areas extending from Airdrie north by Cumbernauld, and east by Slamannan and Falkirk to the Carron coalfield.

Mr. Craig returned to his duties in Scotland in June and proceeded to Mull, where he carried on field-work till the autumn. Thereafter he completed his indoor work and retired from the service in October.

### 1.—West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. E. H. Cunningham Craig, B.A., Mr. W. B. Wright, B.A., Mr. H. B. Muff, B.A., Mr. E. B. Bailey, B.A., } Geologists.

In this district the work was carried on in the one-inch maps 35, 44, 53 and the parts of 43 which adjoin 35. The areas surveyed are naturally divisible into three sub-districts, which are so different in their main geological features that it is advisable to describe each separately. They will be taken up in the following order;—

1ª Glencoe and Glen Nevis.
1ᵇ Islands of Mull and Lismore.
1ᶜ Island of Colonsay.

In consequence of memoir work, Mr. Clough was unable to take part in the ordinary field-work.

## 1ª *Glencoe and Glen Nevis.*

### HIGHLAND METAMORPHIC ROCKS.

Some time was spent in examining the relations of the schists near the junction of the one-inch maps 53, 54, 45, and 46. It appears probable that the flaggy fine-grained quartzite in the river Orchy near the foot of Allt Broighleachan, one-inch map 45, is on the same horizon as that near Dalness, Glen Etive, one-inch map 53, which at present is referred to the Glencoe Quartzite Group. It seems to vary greatly in development in closely adjoining localities, but is usually found, in some form or other, in a position between a great mass of biotite granulite, included in the Moine Series,[1] and a thick pelitic schist or gneiss, which is often garnetiferous. In some places a calc-silicate—well seen in Allt Coire an Easain—intervenes between the flaggy quartzite and the pelitic rock. It is impossible at present to say which of the beds mentioned was originally the topmost, or whether in some places the original relations between them may not have been substantially altered by the movements to which they have been subjected. The strata appear to have been affected by more than one great fold with gently inclined axial plane. Messrs. Clough an Bailey.

The work of previous years in the schistose district lying between Glen Nevis and Glencoe, has been continued, and various outcrops of quartzite, mica schist, and granulites of the Moine Series have been separated. Several imposing examples of complicated folding have become apparent, but doubt still remains as to how far apparent repetitions in the sequence can be accounted for by this folding. Messrs. Wright a Bailey.

### LOWER OLD RED VOLCANIC ROCKS AND ASSOCIATED INTRUSIONS.

*Glencoe.*—In this area the boundary of the Ben Cruachan granite mass has been completely mapped. The junction of the granite with the Lower Old Red volcanic series is no less than 12 miles in length, and all along this line the granite causes contact-alteration in the Lower Old Red rocks. Mr. Muff

*Ben Nevis.*—An examination of the lavas, which form the upper 2,000 ft. of Ben Nevis was begun, but had to be abandoned on account of continuous bad weather. The lavas appear to be all hornblende-andesites very like those of Glencoe. Some of them exhibit the brecciated structure seen in the latter, and it is thought that the amount of agglomerate entering into the volcanic series has been exaggerated.

### PLEISTOCENE.

*Glen Nevis.*—The *massif* of Binnein Mor presents a remarkable topographical peculiarity which probably finds its Mr. Wri

* This term is here used in the sense employed in the Central Highlands.

explanation in the glaciation of the district. The northern and eastern spurs of the mountain, which culminate in the summits of Binnein Beag and Sgor na h-Eilde, are both trenched by passes with flat summits occupied by lakes. The huge valley, Coire Binnein, that lies between these spurs, was a distributing reservoir for ice during the later stages of the glaciation, which overflowed by these passes. The ice-tongue which escaped over the Sgor na h-Eilde Pass can be proved by its striæ to have swept round and become confluent with the Loch Eilde glacier, while that which had its outlet between Binnein Beag and Binnein Mor was tributary to the Glen Nevis ice. To the excavating action of these lateral glaciers and to their moraine accumulations must be ascribed the peculiar flat summits of these passes and the lakes which occur on them. On the slopes of Allt Coire na Gabhalach, below the Binnein Beag pass, there is an enormous accumulation of morainic débris dropped by the northern tongue during its retreat.

### ECONOMICS.

The Loch Leven Water and Electric Power Company have, pending the completion of their larger power station, of which a short account was given in the SUMMARY OF PROGRESS for the year 1905, p. 101, erected a smaller factory half way up the glen. Through the kindness of the engineer of the Company we are enabled to publish the following brief account of this temporary station:—

"The factory is situated about 3½ miles from Kinlochleven, in proximity to a power station laid down and used by the contractors for the driving of their aerial rope-way, electric cranes, etc. A head of close on 400 feet is utilised and the power developed is between 3,000 and 4,000 B.H.P.

"A corrugated iron factory has been erected and a number of wooden buildings for the accommodation of staff and men. A total of about 70 men will be employed at this station.

"Raw materials and finished product are dealt with by means of a light railway from the wharf to the site."

The factory started work on Christmas Day, 1907, and is now producing aluminium.

## 1b *Islands of Mull and Lismore.*

### HIGHLAND METAMORPHIC ROCKS.

ningaig. *The Ross of Mull.*—With the exception of a few intrusions, the island of Soa is almost wholly composed of coarse gneissose rocks, often hornblendic, which strike north-west, and are referred to the Lewisian gneiss of the North West Highlands. They are occasionally crossed by pegmatites of considerable thickness, but no foliated basic intrusions have been observed. The gneiss is crossed by numerous epidotic strings, many of

which represent lines of fault striking N.N.E. and inclining steeply eastward.

The rocks between Bunessan and the coast to the south, from Ardalanish Bay to Traigh Bhan an Sgoir, consist chiefly of pelitic gneiss closely resembling gneisses of the Moine series of the Northern Highlands. This correlation is strengthened by the occurrence in it, near its present base, of a much folded siliceous band which contains abundant garnets and blades of hornblende,* but no zoisite has yet been detected in it. Some thin adjoining seams, of compact texture and leaden colour (13,426), have been found by Dr. Flett to be very rich in apatite.

The upper part of the pelitic gneiss becomes flaggy and is overlaid by a group of quartzo-felspathic granulites, some of which show distinct remains of clastic grains. Towards the top of the granulites, semi-pelitic biotite schists begin to appear.

The folding is vertical or nearly so, and the pitch is southward at rather gentle angles.

West of the main mass of the gneiss, many large patches of hornfelsed pelitic gneiss are entangled in the Ross of Mull granite, but before the intrusion of the granite these patches appear to have been in much the same condition as the pelitic gneiss further east, near Bunessan. They do not appear to have approximated in character to the less altered sedimentary rocks of the northern part of Iona.†

An intrusive sill composed of garnetiferous hornblende schist is repeatedly folded at the base of the pelitic gneiss for some distance east and north of Ardalanish Bay. In certain places it cuts distinctly across the bedding planes of the adjacent gneiss.

*Lismore Island.*—The mapping of this island was completed. The schists of which the island is composed, viz., a dark bluish limestone-schist and a black schist, possess the same characters and bear the same relation to one another throughout the whole island as described for the northern end of the island, in the SUMMARY OF PROGRESS for 1901. Mr. Muff.

*South-east Corner of Mull.*—In addition to the work begun in the Ross of Mull, a beginning was made in that low lying corner of the island which fills up the angle between the Sound of Mull to the north-east and the Firth of Lorne to the south-west. The Lismore limestone, accompanied by grey slates, comes to the surface in the tract between Lochs Don and Spelve, under conditions to be presently described. Its grade of metamorphism is very low. The occurrence is of some importance since it indicates that the Great Glen fault Mr. Bailey.

* See "Summaries of Progress" for 1897, p. 41; for 1900, p. 10; for 1902, p. 85; and others.

† Sir A. Geikie's Lecture before the Royal Institution, 1889, on "Recent Researches into the Origin and Age of the Highlands of Scotland and the West of Ireland." This lecture appears in *Nature*, vol. xl., pp. 299 and 320.

must lie to the north-west, well within the area of the Tertiary lavas.*

PALÆOZOIC, MESOZOIC, AND TERTIARY ROCKS.

Mr. Cunningham Craig.

*The Ross of Mull.*—The Ross of Mull granite occupies most of the area, more than five miles in length from east to west, between Ardalanish Bay and the Sound of Iona, and it extends also at least four miles out to sea, in a south-westerly direction, to the Torran rocks. It is a reddish, rather coarse-grained biotite granitite, not chilled at the margins, and without any conspicuous felspar phenocrysts. The eastern margin near Rudh'Ardalanish is very irregular, sill-like bands extending in all directions from the main mass into the adjoining gneisses.

Professor Judd considered the granite to be of newer Palæozoic age,† and this view has been strengthened this year by the discovery (1) of a thin basic sheet which cuts the granite on the east side of the Sound of Erraid, and (2) of a sill of granitoid porphyry with chilled margins, which cuts veins of granite in Ardalanish Bay. The basic sheet (13,414) referred to is described by Dr. Flett as a porphyrite with affinities to malchite.

The number of gneissic masses entangled within the granite is surprisingly large. The larger masses possess the same strike as the main mass of gneiss east of the granite, and they cannot have been floating in the granite magma.‡ It seems probable that they represent portions of the floor below the granite, a floor which was obviously very irregular.

Of somewhat earlier consolidation than the granite are many masses, both large and small, of diorite, which are found within the granite and repeatedly cut by granitic strings. One of the largest of these masses forms Eilean a'Chalmain and is more than half a mile long in an east and west direction.

The basaltic sills of Tertiary age become numerous near the basalt plateau which appears a little north-east of the area mapped. Some of the sills have been traced more than a mile and are occasionally as much as 15 ft. thick. They appear, as a rule, to have been intruded along nearly horizontal joint-planes through nearly vertically folded beds.

The island of Dubh Artach, which lies more than 14 miles south-west of the Ross of Mull, is composed of dolerite, which is probably part of some Tertiary intrusion, but no junction with any other rock is exposed.

* It is not known at present whether the Tertiary lavas are in any way affected by this important dislocation.

† "The Secondary Rocks of Scotland. Second paper. On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata." *Q.J.G.S.*, vol. xxx., 1874, pp. 244 and 290.

‡ J. G. Goodchild, "On a Granite Junction in Mull," *Rep. Brit. Assoc.*, 1892, p. 722.

*The South-east Corner of Mull.*—The researches of Professor Judd* have made us acquainted with the presence at Duart of various fossiliferous divisions of the Lias, appearing from beneath the Tertiary lavas, and themselves underlain by conglomerates, referred by him to the Triassic system. Liassic rocks were also shown to occur further south at the entrance to Loch Spelve. He also referred an extensive tract upon his sketch-map to the volcanic rocks of Lower Old Red Sandstone age.† His evidence for regarding these lavas as older than the Mesozoic sediments was obtained in the district lying to the south of Loch Spelve, and is strikingly confirmed by the relations now known to exist between these rocks in the peninsula between this loch and Loch Don to the north. Mr. Bailey.

In Sir Archibald Geikie's general map of Scotland (1892) an additional outcrop of Jurassic strata is shown stretching south from Loch Don, and Professor Judd's Old Red volcanic rocks, originally made to cover far too extensive an area, are no longer represented as such, but a small portion more nearly corresponding with the true outcrop of the group is coloured as an acid intrusion.

The results of the recent examination of the ground, which is not yet completed, lead to the following conclusions. The Jurassic rocks of Duart and those reaching south from Loch Don are parts of a continuous outcrop brought to the surface by a sharp anticline which runs, with curving axis, from Craignure Bay to Loch Spelve. On either side the Tertiary basalts follow; their eastern outcrop is a narrow one, being restricted to the central portion of a syncline which on this side flanks the anticline just referred to. Further east the steep dip brings up the Jurassic rocks once more, so that exposures of them are met with at intervals along the extreme edge of the coast between Lochs Don and Spelve.

The chief interest is concentrated in the area lying to the south of Loch Don, where the two limbs of the anticline are nearly vertical with an average outward dip of about 80°, and where the following succession is clearly exposed on both sides of the central axis.

It is noteworthy that the older lavas have undergone a brecciation and decomposition not shared by the Tertiary basalts. It is this feature probably which attracted Professor Judd's attention, for it certainly does give them an appearance of greater antiquity. Strange as it may seem, no pebbles of these lavas have been noticed in the overlying sediments, even where the quartz-conglomerates (?Trias) rest directly upon them. In other clear sections the conglomerates are unrepresented, and the older volcanic rocks are in contact with the Liassic limestones, so that the existence of an overlap at the

* "The Secondary Rocks of Scotland. Third paper. The Strata of the Western Coast and Islands." *Q.J.G.S.*, vol. xxxiv., 1878, p. 660.

† "The Secondary Rocks of Scotland. Second paper. On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata." *Q.J.G.S.*, vol. xxx., 1874, plate xxii., opposite p. 302.

base of the Secondary Rocks is fairly evident, although one cannot describe the unconformity here as striking. But then, if these problems were being attacked *de novo*, the same might be said of the equally great unconformity at the base of the Tertiaries. A flint conglomerate it is true underlies the basalts, and this in itself is of course sufficient, in the present state of our knowledge, to indicate the denudation of the chalk, but any actual discordance between the dip of the Tertiary rocks and the underlying Lias has not yet been observed in this district. Even at the lowest of the three unconformities there is, as a rule, only a very poor development of basement breccia between the schists and the overlying lavas. A definite though slight divergence of strike has, however, been noticed in certain junction sections in this last case.

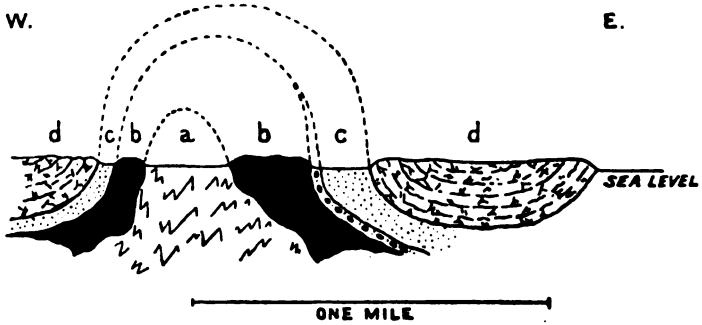


FIG. 2.—*Section across the Loch Don Anticline. By E. B. Bailey.*

*d*. Tertiary Lavas.
Unconformity.
*c*. Lias (and ?Trias on east side only).
Unconformity.
*b*. Older Lavas (?Lorne Traps).
Unconformity.
*a*. Schists (Lismore Limestone and grey slates).

An important feature is of course the complete degradation, by denudation, of the anticlinal arch (cf. Fig. 2), but the effect of the various rock groups in determining the minor inequalities of the surface is also of interest.

At present, however, the most interesting point in connection with this fold is the clear example it affords of the high degree of disturbance which characterises the Tertiary rocks throughout a considerable tract of eastern Mull.

## PLEISTOCENE AND RECENT.

*The Ross of Mull.*—Small patches of boulder clay fill up hollows on the western side of some of the hills, but none of

these show good sections. Most of the glacial striæ run slightly north of west.

The three raised beaches generally entitled the "100-foot," the "50-foot," and the "25-foot," respectively, are all represented, though the levels do not correspond exactly to the heights named.

*South-east Corner of Mull.*—The numerous striæ preserved in this corner show that the Loch Linnhe current of ice split upon the island much in the same way as Mr. Harker* has shown that the mainland ice parted on Skye. One great stream found its way down the Firth of Lorne, the other escaped through the Sound of Mull. Most of the foreign boulders stranded on this part of Mull have come from the north side of the Great Glen fault. Mr. Bailey.

## ECONOMICS.

*The Ross of Mull.*—The Ross of Mull granite was formerly quarried at Erraid, where stone was obtained for the Skerryvore and Dubh Artach lighthouses. Blocks of unusually large size can be obtained, and the rock generally appears very fresh. Mr. Alan Stevenson, in his "Account of the Skerryvore Lighthouse" (1846), states that the granite, though not so hard as the Aberdeen granite is still of excellent quality, and, speaking of the Erraid quarry, he says, pp. 110—111, "I have never seen a granite quarry of equally great resources, as regards both the quantity and the quality of the material produced. The rock in general yielded easily before well-directed shots, and was separated into large masses, capable of being advantageously cut, with little loss of material, into shapely blocks, by means of wedges, which work remarkably well in that rock." In another passage, p. 149, he says, "There is good reason also for concluding that the Mull stone is sufficiently durable, because it contains but a small proportion of micaceous matter, and in its texture closely resembles some of the blocks of St. Oran's Chapel, which have resisted the action of the weather, it is believed, for more than 600 years and still retain the marks left by the tools of the workman." Mr. Cunningham Craig.

The uncultivated ground, which much exceeds the rest in extent, is used as sheep pasture, and supports also some grouse and rabbits. The amount of arable ground is very small. Peat mosses cover a considerable area and provide most of the fuel used in the district.

The blown sand, which has been carried inland to a considerable height in the bays east of Port Uisken, is almost entirely shell-marl, and would probably make an excellent top dressing for pasture.

* "Ice Erosion in the Cuillin Hills, Skye." *Trans. Roy. Soc. Edin.*, vol. xl., p. 221, 1901.

r. Bailey. *South-east Corner of Mull.*—The recent work has been disappointing in dispelling all hope of finding coal in or under the Secondary rocks of this area. Freestones suitable for building purposes have been noticed among these rocks. The most promising exposures have not yet been opened up, although poorer bands outcropping by the roadside have been quarried for local purposes.

r. Muff. *Lismore.*—The limestone is burnt for lime at Port Salen and Port Ramsay in the ordinary inverted cone-shaped kilns. The lime is yellowish in colour, and contains a small proportion of quartz and mica. It is used mainly for lime-manuring by the farmers on the West Coast, and to a less extent as a building lime. The demand is not sufficient to provide constant employment throughout the year.

Trials for roofing-slates have been made in the black schist of Eilean na Cloiche, one of a group of islands situated between Lismore and Oban. The quantity of slate is too small, and the situation (being mostly below high-water mark) too inconvenient for slates to be worked here profitably. On Lismore the black schist is so much affected by strain-slip-cleavage that it is impossible to split slates from it.

## 1°. *Island of Colonsay.*

### METAMORPHIC ROCKS AND ASSOCIATED INTRUSIONS.

essrs. right and iley. The islands of Colonsay and Oronsay are, geologically, as pointed out by Dr. Peach,* merely a continuation of the Rhinns of Islay. The country rock in each consists of a mass that is presumably Lewisian Gneiss and a sedimentary series of supposed Lower Torridon age. In instituting a comparison between the two areas one can, however, place no reliance on arguments founded on the relation existing between the Lewisian and Torridonian rocks, since in Colonsay at least this relation is far from obvious; there remains merely the criterion of similarity of lithological type, but this of itself is sufficiently strong to justify Dr. Peach's correlation in so far as it places the Colonsay-Oronsay sedimentary succession in the same great group as the Kilchiaran slates and grits of Islay. This similarity, which is in a general way so marked, does not, however, extend to the details of the stratigraphical succession, and it is possible, or even probable, that we are in these islands dealing with rocks somewhat higher in the succession than those of the Rhinns.

Fortunately the state of exposure of the sedimentary rocks of Colonsay and Oronsay has made a detailed study of their stratigraphy a matter of comparative ease. They have been found to constitute a single conformable sequence, of great thickness, containing within its limits several well contrasted lithological types. These are arranged somewhat in dovetail

* "The Geology of Islay," *Memoir of Geol. Survey of Scotland*, p. 25, 1907.

fashion, so that the same kind of rock is often met with on different horizons, while a subdivision, important in one locality, may thin away and become unrecognisable in another. It has been found convenient to distinguish the following groups, which are enumerated in descending order:—

8. Staosunaig Black Phyllite Group.
7. Colonsay Limestone Group.
6. Kiloran Banded Flag Group.
5. The Millbuie Epidotic Grit, Grit and Grey Phyllite Group.
4. Kilchattan Grey Phyllite and Sandstone Group.
3. Machrins Grit and Mudstone Group.
2. Dungallain Epidotic Grit Group.
1. Oronsay Sandstone and Mudstone Group.

Groups 6 and 8 are very constant throughout the island, and of easily recognisable character; and group 7 always contains at least one important bed of grey sandy limestone. The remaining subdivisions, however, are not only exceedingly variable, but also exhibit the same type of rock developed on different horizons. Thus, epidotic grits, similar to those of the Dungallain Group, and white grits, indistinguishable from those of Machrins, both recur in group 5, and grey phyllites are found on different horizons in both the Kilchattan and Millbuie Groups. These grey sandy phyllites are, however, essentially distinct from the much darker and purer phyllites of Group 8. The Oronsay sandstones are of a grey colour, and contrast markedly with the purer felspathic grits of Groups 3 and 5, and the mudstones of Groups 1 and 3, though somewhat similar in composition to the Kiloran Flags, yet lack the beautiful banded bedding of this horizon, and are less siliceous.

On the whole, therefore, we are dealing with a succession the members of which, in spite of recurrence of type, are fairly distinct from one another; and, were it not for the rapid lateral variation which is apparent even within the narrow limits of these islands, it might even be regarded as sufficiently well characterised to afford grounds for distant correlation. As an example of this lateral variation we may cite Group 5. In the neighbourhood of Millbuie it consists of three members, namely, phyllite, white-weathering felspathic grit, and epidotic grit; but this tripartite division is only local. North of the road from Scalasaig to Machrins the epidotic grits, if represented at all, become too poor to be distinguished, while the white grits above them do not extend further north along the outcrop than Loch Fada, beyond which the phyllites alone persist. South of Millbuie, on the contrary, both the phyllites and the white grits die out, neither extending further south than Loch Cholla, while the epidotic grit continues with considerably altered characters to the sea at Balaruminmore, being here the only representative of this group. Curi-

ously enough, however, the tripartite division of Millbuie, which was found to break down as the group was followed along its outcrop to the north, re-appears in full force in the fine exposures, stretching from coast to coast, south of Balnahard in the north end of the island. These belong to a distinct outcrop lying upon the far side of the Kiloran syncline, to be shortly referred to.

With groups such as this, which may become unrecognisable within a mile, there is little hope of effecting an exact correlation either with Islay on the one hand or Skye on the other. Even in Groups 6—8, which, as we have mentioned above, are fairly constant within the limits of the island, one can have little confidence. With regard to a possible correlation with the Diabaig rocks of Skye, Mr. Clough, who originally mapped the district of Sleat where these rocks are most fully developed, after seeing the Colonsay succession, expressed the opinion that there is sufficient resemblance between the assemblage of rock-types in the two areas to warrant the conclusion that they belong to the same group. The same view was, of course, implied in Dr. Peach's correlation of the Oronsay rocks with those of the Rhinns of Islay. Further than this it is impossible to go. The Torridon beds of Colonsay form, therefore, a connecting link between those of Islay and Skye, but as to their exact relation to either, nothing is known.

The finding of quartzite pebbles in the strata that have been correlated with the Torridonian is a point of some interest, proving, as it does, that there existed before their deposition consolidated quartzites indistinguishable from some in the Highlands. These pebbles are never abundant, but they are most noticeable in the conglomeratic bed which adjoins the gneiss at Leac Buidhe, near the north end of the island. Here they reach a diameter of a couple of inches and are of two types, one being a fine grained greenish quartzite weathering very white, and the other a white quartzite with well marked clastic grains of pure quartz. The latter has also been found in the Dungallain Epidotic Grit Group at Turnicil.

The presumed Lewisian Gneiss occurs at the north end of Colonsay, on the southern slopes of Leac Buidhe overlooking the sandhills. The whole area is less than an eighth of a square mile, but the exposures are sand worn and remarkably clean. In the opinion of Mr. Clough it does not conform very well to the ordinary types of Lewisian Gneiss seen elsewhere, being less markedly hornblendic. Both the banding of the gneiss and the bedding in the Torridon are obliquely cut off by the line of junction of these rocks. At a distance of from 10 to 30 ft. from the margin of the gneiss the sediments contain a massive bed of conglomerate, containing well rounded quartzite pebbles, but apparently not a fragment of gneiss.

Intense folding is apparent in many clear sections throughout the greater part of Colonsay and Oronsay, yet the structure

is in its main features comparatively simple. The obvious folds, which occur everywhere, cause isoclinal repetition on a small scale, but are not accompanied by any of sufficient magnitude to complicate the relations of the various rock-groups to one another. By far the greater part of the two islands, in fact all the country lying to the south-west of Kiloran, is characterised by simplicity of structure, the rocks dipping on the whole towards the east and north-east at gentle angles. Upon the other side of Kiloran, however, a rather complicated anticlinal and synclinal structure lends variety to the country, and even presents features, which in some cases are difficult of interpretation.

The folds referred to above can be proved to belong to two systems differing widely in age. The earlier system, though somewhat difficult to distinguish, is accompanied throughout the islands by a well marked cleavage. This manifests itself in the softer phyllite beds as an incipient foliation, which seems to be generally parallel to the bedding, but nevertheless can be repeatedly seen to cross it. This latter relation is well shown along the west coast of Oronsay.

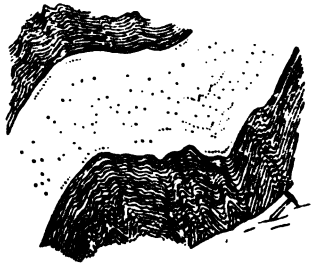

FIG. 3.—*Lamprophyre dyke on shore N. of Port an Obain, Colonsay, intruded along cleavage of primary movement, and involved in the folding of the secondary movement.*

The planes of this primary cleavage are affected, especially near the east coast of both Colonsay and Oronsay, by pronounced folding, and this secondary folding where most marked is accompanied by a coarse cleavage. It is found that a great number of the lamprophyre dykes and sheets which traverse the island are obviously intruded along the first foliation, and, as obviously, folded and cleaved by the secondary movement. These run in a general way parallel to the strike of the first cleavage, dip along it, and occasionally cut across it in such a manner as to leave no doubt that they are subsequent to it. The extent to which they are affected by even the minuter folding of the secondary movement, and traversed by its cleavage, shows that they were intruded before this movement. Moreover, where the secondary folding is most intense the proportion of lamprophyres found to be folded and cleaved is much greater. Thus, in traversing the island

from west to east, belts of gradually increasing intensity of secondary folding are passed over, and at the same time the lamprophyres are found to have suffered both in greater numbers and to a much greater extent. On the west coast, where the secondary crinkling is slight, the very smallest dykes are not affected or but slightly so, while on the east side of the island even the largest are folded and sheared to such an extent as to be at first sight difficult to distinguish from the adjoining schists.

The two movements are, therefore, distinct, and are separated from one another by the period of intrusion of the dykes. But this is not all. The syenitic mass exposed on the shore in Kiloran Bay is intermediate in age between the first movement and the lamprophyres. Its marginal breccia contains angular fragments of the surrounding Torridonian rocks, clearly showing the primary cleavage, and both syenite and breccia are traversed by dykes affected by the secondary cleavage. Moreover, these dykes are chilled against the syenite, which is thus shown to have been cool before their intrusion. It may, therefore, fairly be said that between the primary and secondary movements sufficient time elapsed for,

(1) The intrusion of a fair sized plutonic mass.
(2) The cooling of the same, and
(3) The subsequent intrusion of an extensive series of dykes.

A remarkable case of incorporation and solution of sedimentary material in a magma is presented by the above mentioned syenite in Kiloran Bay. The exceedingly hornblendic marginal portion of this rock has caught up in its mass numerous blocks and rounded boulders of quartz and quartzite, the margins of which it has corroded in a remarkable manner. Halos of felspar surround these half-dissolved fragments, being an obvious product of their solution. It is hoped that microscopical examination will throw some light on the nature of the changes that have taken place.

## TERTIARY?

Throughout the whole of Colonsay and Oronsay there can be traced a very old and much denuded plain of marine erosion cut in the solid rock, and in places backed by magnificent cliffs. In Uragaig, where it attains its finest development and is best preserved, its inner angle lies at a height of about 135 ft. above high water mark of spring tides. In other parts of the island, although its altitude cannot be so exactly determined, it appears to be at much the same level, but may be somewhat lower towards the south. With regard to the period of its formation little is known except that it is clearly pre-glacial, and had suffered considerable denudation before the advent of the ice.

### PLEISTOCENE AND RECENT.

The post-glacial raised beaches in Colonsay are on the whole poorly developed. Even the Neolithic, or so-called "25 ft." sea, which cut such marked terraces along the shores of the fjords on the mainland of Scotland, produced little effect of this kind here. Shingle banks of this age are, indeed, not uncommon, and indicate a sea level some 22 or 23 ft. above the present, but no well marked rock terraces have been developed. The ice-planed slopes which rise from the sea on the east side of the island have, in most places, little to show for this prolonged period of higher sea level, except a slight corrosion and breaking up of their surfaces. In the sandhills at Balnahard at a height of 22 ft. above h.w.m., and not extending below this level, is a well marked Neolithic floor with worked flints.

Shingle beaches of the older, presumably late-glacial, seas are also well developed locally at two distinct levels, the upper corresponding to a sea level about 100 ft., and the lower to a sea level about 60 ft. above the present.

### ECONOMICS.

During a recent visit to Islay an abundance of beautiful clean quartzite gravel was observed in some of the bays along the coast south-west of Mala Bholsa, half-way between the Rudh a' Mhail and the mouth of Loch Gruinart. It is of the first quality, being well rounded and of exceptional purity. As an ornamental gravel it ought to fetch the highest prices on the market, and might possibly be available as a source of quartzite for the manufacture of silica bricks. The coast is not of a nature to be injured by the removal of the gravel, and small boats carrying coal to the Western Isles might bring it back as ballast. There is an almost inexhaustible supply of similar gravel in the raised beaches along the coast, but it lacks the cleanness of that on the modern shore.

At Balnahard, in the north of Colonsay, there is a mass of Kentallenite, probably more than 20 acres in extent, similar to the much sought after Ballachulish stone. It is not, however, easily accessible, and the difficulty of putting it on the market would probably be great.

## 2.—North Highland District.

Comprising parts of the Counties of Inverness and Caithness.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. J. S. Grant Wilson,
Mr. C. B. Crampton, M.B., C.M.,
Mr. E. M. Anderson, M.A., B.Sc., } Geologists.
Mr. R. G. Carruthers,
Dr. J. Horne (Acting),

The Survey of Sheet 74 has been completed by the mapping of 129 square miles on either side of the River Findhorn and in the upper valley of the Dulnan; together with smaller isolated areas at Flichity in Strathnairn, between Kinveachy and Carrbridge, and to the north-west of Newtonmore in the extreme S.W. corner of the map.

The whole of this moorland area is practically under deer and grouse, the grouse moors also carrying a limited number of sheep. The steep hill slopes of the main valley of the Findhorn and its chief tributaries afford good grazing, and scattered patches of cultivated land occupy the wider stretches of the river flood plains.

## HIGHLAND METAMORPHIC SERIES AND ASSOCIATED IGNEOUS ROCKS.

The south-eastern side of Strathdearn, the name given to the valley of the Upper Findhorn between Tomatin and Coignashie, is mainly occupied by the metamorphic rocks of the Moine Series, those of the pelitic and semi-pelitic type being largely predominant over the more siliceous varieties. The general strike of the schists and of the longer axes of the major folds into which they have been thrown is approximately N.N.W. and S.S.E., and the dip almost invariably in an easterly direction, showing that the system of folding is isoclinal. This plication is probably of a more complex nature than that indicated on the map, the minor flexures being for the most part concealed beneath the wide-spread covering of drift and hill peat.

In general lithological character these rocks do not differ markedly from those previously described in adjoining areas.* At the head of the northern Allt a' Mhuilinn, which joins the Findhorn opposite Daltomach, there is, however, a band of highly siliceous rock which varies from the ordinary type of siliceous Moine Schist in the entire absence of biotite. It is a white-weathering yellowish quartzite, often entirely made up of quartz in large rounded granules which have somewhat the appearance of having been partially fused together, and in this particular resembles the quartzite of Aberdeenshire where affected by the newer granite. Parts of the rock contain a fair amount of felspar, and white mica is often developed on the divisional planes.

A similar rock occurs—much along the same line of strike—in the Dulnan Valley, three miles to the south. It is well exposed along the course of the Allt Airidhe nan Eag, and forms an irregular mass, whose western margin crosses the Dulnan a mile above its junction with the former stream, and extends to the S.E. as far as the Allt Fethlinn. In this locality the quartzite lies between siliceous Moine schists on the east, and a large area of semi-pelitic rocks on the south-

* "Summary of Progress" for 1904, p. 81; 1905, p. 110; 1906, p. 85.

west, while on the Allt a' Mhuilinn, where it is largely peat-covered, it appears to be associated with semi-pelitic flag-stones. The greater part of the basin drained by the head waters of the Dulnan, above the junction of that stream with the Allt Fethlinn, is occupied by fine grained mica-schist or micaceous granulite, of a type intermediate between the siliceous schists and the more coarsely micaceous pelitic gneiss of the Moine Series. This intermediate character of the rocks increased the difficulty of differentiating the several types; and, with the exception of one or two more siliceous bands, they have all been included in the pelitic zone. The general strike throughout most of the area is north-westerly, with a south-westerly dip. The direction of stretching is parallel to the strike and roughly horizontal along the bedding planes. Bands of hornblende schist have been met with in several places within the semi-pelitic area of the Upper Dulnan basin. These lie on the same line of strike as the hornblende schists previously mapped on A' Bhuidheanaich, further to the south; but whether they represent one continuous band, repeated by folding, there is not sufficient evidence to determine.

The metamorphic rocks of Strathdearn are pierced by numerous granite protrusions, both in the form of large irregularly shaped masses and in smaller bosses, dykes and veins. Besides these intrusions of definite form, there is a wide spread *lit-par-lit* invasion by granitic material, which in some cases has so completely impregnated the schists that they cannot be readily distinguished from an original igneous rock. (See Fig. 4, p. 78.)

Mr. Hinxma

Some interesting examples have been observed in which the characteristic quartzo-felspathic lenticles of the pelitic gneiss are crossed, both by a granite vein cutting the foliation planes and by the *lit-par-lit* intrusions which it feeds, showing that these quartz-felspar veins, which are probably of segregative origin, are earlier than the intrusion of the unfoliated granite.

The predominant igneous rock is a medium grained pinkish granite, containing phenocrysts of orthoclase, a moderate amount of biotite, and no white mica. Rocks more acid in type, and probably of slightly later intrusion, are represented by the aplite and muscovite-pegmatite veins found between the southern Allt a' Mhuilinn and the Allt Fionndairnich, and by numerous dykes of pink or brick-red felsite and quartz porphyry that occur in many parts of the area.

A basic modification of the ordinary type of granite forms part of the intrusion that flanks the hillside between Clune and Knockandoo. In its most basic form the rock is a dark garnetiferous augite diorite of a remarkable character. It is thus described by Dr. Flett. "It consists mainly of dark green hornblende, yellow green augite, plagioclase felspar and reddish garnets. The garnet, hornblende and felspar are in irregular crystals which are compact near their centres (as a rule), but at their edges are intergrown with the felspar in graphic fashion. The felspars are smaller than the abo

named minerals, but it is often possible to prove that adjacent grains, embedded in augite or hornblende, have simultaneous extinctions. Graphic intergrowths of these minerals form a considerable part of the rock. They are most pronounced in the augite, which may form a perfect network with interstices occupied by felspar. The hornblende shows the same phenomenon usually only at its margins, while in the garnet it is rare and occurs only on a small scale. Parallel intergrowths of augite and felspar have been described and figured by Dr. Teall in his British Petrography (Pl. XXIII., Fig. 2). No instance, however, is known to me in which garnet, hornblende and augite show this phenomenon in the same rock. Its significance is not altogether clear. The other minerals present are iron oxides, sphene, and rutile. The felspar is mainly labradorite, and varieties of plagioclase appear to be absent."

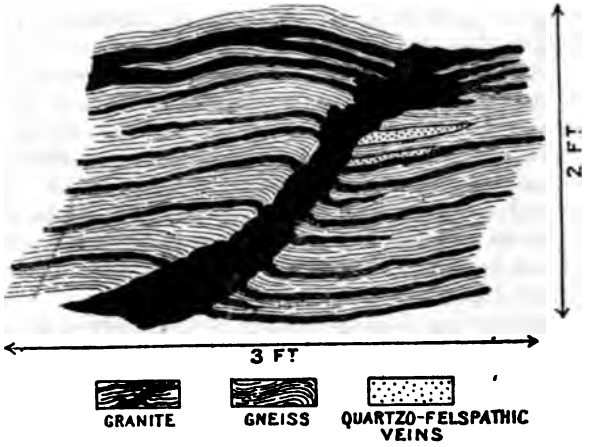


FIG. 4.—*Granite vein crossing the foliation planes of a flaggy pelitic gneiss and feeding successive "lit-par-lit" intrusions. Earlier lenticles of quartzo-felspathic material are cut by both trunk and branch veins. Allt a' Mhuilinn, Strathdearn. Sheet* 74.

This basic type passes into an intermediate rock,—a quartz diorite with hornblende and biotite, and this again into the normal biotite granite of the district.

Carruthers. The area mapped by Mr. Carruthers in the upper basin of the Findhorn between Coignafearn and the western edge of Sheet 74, may be conveniently divided into two portions. One of these, including the main river valley and the area to the north of the Findhorn as far as Beinn Bhreac Mhor, presents a complex of granite and schistose rocks. The other, which extends southwards from the river to the watershed at the head of the Elrick Burn, is mainly occupied by the types of pelitic and siliceous schist of the Moine Series, previously

described in the region further to the east, and affording no special features of interest.

The granite of the northern area is evidently an extension of the protrusions further down the Findhorn valley. In this region it occurs, not as a solid mass, but in the form of innumerable intrusions along the divisional planes of the metamorphic rocks. These intrusions on the whole follow the predominant N.E. and S.W. foliation of the schists, but are themselves unfoliated. In lithological character the rock is almost wholly of the normal biotite-granitite type, but two interesting modifications, the one extremely rich in hornblende, the other containing a plentiful sprinkling of small garnets, were observed. Both occurrences are of small extent, but clearly form part of the newer granite intrusion.

The granite is occasionally pierced by thin dykes of a fine-grained more acid rock, while similar dykes are abundant in the surrounding schists.

Special interest, however, attaches to a more basic series of dykes and sills, the age of which is uncertain. The smaller of these intrusions are well foliated throughout, the larger only in their marginal portions, leaving a core of unfoliated rock. While most of these dykes when sheared give rise to a green chloritic schist of well-defined type, a few of their number, when in their greatest stage of alteration, approach so closely in their field aspect to the thin bands of pelitic gneiss so common in the district, that the two rocks can hardly be separated. A microscopic examination of these rocks has yet to be made.

The intrusive nature of these dykes and sills is still evident, and the great majority are clearly seen to transgress the foliation planes of the surrounding schist. The foliation of these intrusions is commonly parallel to that of the schists, but in one case at least is at a considerable angle to the latter, just as the cleavage of a hard band of rock is often at an angle with that of the adjacent bands of softer shale.

The greatest development of these foliated intrusions is found on the Elrick Burn, between one and two miles from its junction with the River Findhorn.

The schistose rocks of Glen Mazeran form the southern prolongation of an area already described in former Reports,* and afford no new facts of interest. Mr. Wilso

The limestone bands mapped to the north of the Kyllachie Burn by Dr. Horne have not been traced beyond that stream, and appear to die out before reaching Glen Mazeran. A thin band of crystalline limestone, associated with calc-silicates and pelitic schist, was, however, met with by Mr. Hinxman near the head of the Allt Lathaich, on the opposite side of Strathdearn.

The newer granite intrusion of Moy has been traced southwards across the Kyllachie and Mazeran Glens, and its eastern

* Summary of Progress, 1904, p. 80; 1905, p. 110.

and western boundaries defined. The general lithological character of this mass has already been described.* In the Glen Mazeran area it appears to be usually a coarse porphyritic biotite granite, but the rock is much decomposed and good sections are few.

On the bare rocky hill between Daltomach and Laggan, the altered pelitic sediments are largely impregnated with granitic material, and converted into a coarsely crystalline granitoid biotite-gneiss.

Several small dyke intrusions of fine-grained pink felsite cut both the newer granite and schistose rocks of Glen Mazeran.

Horne. *Strath Nairn.*—The crystalline schists on both sides of the Nairn valley in the north-west corner of the sheet belong to two groups: (1) flaggy quartz-biotite granulites, and (2) garnetiferous muscovite-biotite gneiss, which appear as sub-parallel bands with a variable strike and a highly complicated system of folding. On the precipitous crag west of Brin there is a prominent development of the coarse massive type of the garnetiferous biotite gneiss, where it contains numerous folia and lenticles of quartzo-felspathic material running more or less parallel with the foliation of the rock. Thin bands of epidiorite, passing into hornblende-schist and ultimately into green chlorite biotite schist, appear occasionally among these gneisses, but are traceable for no great distance. Examples occur on the ridge about a mile S.S.E. of Farr House.

A noteworthy feature is the amount of acid igneous material that has been injected in the gneisses in the form of irregular veins of biotite granite and of pegmatite. These sometimes cross the foliation of the schists and isolate small patches of the altered sediments.

Several dykes of quartz-porphyry, displaying chilled margins, traverse alike the gneisses and granitic intrusions, as for instance on Brin Crag, where the main dykes and thin branching veins are clearly shown.

Anderson. *Kinveachy and Carrbridge.*—The schists and gneisses of the Moine Series extend from the edge of the alluvial plain of the Spey at Kinveachy to a point a little west of the summit of Beinn Ghuilbnich, where they are truncated by the margin of the Monadhliath granite. They are mostly siliceous in character but include some micaceous bands, and are much penetrated by granite veins. The siliceous type of rock continues to the north-east, and forms the summit of Creag an Fhithich. Near Ochnoir a fine grained mica-schist is met with, which may form part of the Dulnanbridge complex of rocks described in former Reports.†

The general strike of the rocks between Kinveachy and Grantown is north easterly, the dip to the south-east.

The mapping of the Monadhliath granite has been completed. The main mass consists of a coarse-grained pinkish biotite-granite, but in places a porphyritic variety with quartz

* Summary of Progress, 1904, p. 82.

† Summary of Progress for 1905, p. 112; for 1906, p. 85.

and felspar phenocrysts in a fine-grained or micro-crystalline base has been observed. The relations of this rock to the coarser granite are somewhat obscure, but on the north side of the Dulnan, between Eile and Dalnahaitnach, it appears to form the marginal portion of the mass. In other localities intrusions of very fine-grained rock have been found within the coarser granite close to the junction line of the two varieties, indicating the later origin of the fine-grained rock. The latter is less acid in character than the aplite of Garbh-mheall Mor, described in the Annual Summary for 1906 (P. 85).

Another granite intrusion is met with along the north-western edge of the alluvial tract of the Spey between West Chapelton and Balnacruie. It has much the same lithological character as the coarser portions of the Monadhliath mass, and also resembles the rock which protrudes through the gravels immediately south of Boat of Garten.

## PLEISTOCENE AND RECENT.

Several instances of striated surfaces were noted in the Nairn basin; those in the bottom of the valley near Brinmore range from N. 32° E to E. 42° N. while the markings on the ridge E.N.E. of Flichity House about the level of 1,250 ft. point N. 20 E. **Dr. Horne.**

The River Brin and its tributaries above Achvraid have carved channels through a deep deposit of boulder clay with stones chiefly of local origin. Some of the larger blocks of quartz-porphyry are well striated. At high levels loose morainic material appears in the stream sections, resting on solid rock and covered by peat.

Glen Mazeran is almost entirely covered with loose stony morainic drift, which increases in thickness towards the upper part of the glen and sweeps over the water-shed into the Brin valley. In the main valley, immediately to the west of the Druim Ruadh wood, the deposit reaches a depth of at least 150 ft. Lateral moraines, presenting a rudely terraced arrangement, are a marked feature of this glen. **Mr. Wilson.**

The ridge of the Carn Glac an-Eich, further north along the watershed at the head of Glen Kyllachie is, however, remarkably free from drift, and several striæ, indicating an east-north-easterly movement of the western ice across the water-shed into the Findhorn valley, have been observed on the bare, finely glaciated rock surfaces west of the road that crosses the hill.

A large terminal moraine crossing the Mazeran Burn at Druim Ruadh in a north and south direction, records a halt in the retreat of the western ice up the valley.

A somewhat different disposition of the glacial deposits is found on the east side of Strathdearn. The tributaries of the Findhorn, along their lower and middle courses, are eroding **Mr.**

a thick covering of morainic drift, and have here and there cut down to the underlying boulder clay. Higher up the glens the morainic material gradually thins out, until along the head waters of the streams a hard grey till is exposed beneath the almost universal peaty covering. Few of the carried blocks in Strathdearn can be recognised as of other than local origin. Small fragments of red sandstone, probably coming from the Great Glen, have been detected in Glen Kyllachie, and perched blocks of porphyry from the Spey valley, referred to in the sequel, are found at a height of 2,300 ft. on the eastern water shed.

Mr. Hinxman and Mr. Wilson.

A remarkable and conspicuous feature in the scenery of the Upper Findhorn is the large, pine-crowned moraine that crosses the river valley at Tulloch, a mile above the foot of Glen Mazeran. The steep concave side of this great mound, rising at an angle of 40 degrees, faces northwards down the valley; to the south it falls gradually to the alluvial plain. Although its continuity is now interrupted by the river, it is evident that this moraine was once continuous with the lateral moraine which flanks the hillside above the hollow at Daltomach. The position of a corresponding moraine is indicated on the wooded hill slope on the opposite side of the dry valley. This hollow, which connects the valleys of the Findhorn and the Mazeran burn, is found by a series of levels to fall 103 ft. from north to south. It is now largely filled with drift, but clearly represents the pre-glacial channel of the Glen Mazeran burn, which now flows round the north side of the wooded hill to join the Findhorn at Laggan.

It seems probable that at a time when the floor of the narrow trench-like glen of the Findhorn above Tulloch was bare or partially occupied by an inert or dying glacier, a powerful ice-sheet, derived from a wide gathering ground in the west, poured down over the broad valley of the Glen Mazeran and Kyllachie burns and protruded a lobe of ice through the Daltomach hollow into the Findhorn valley at Tulloch, finally leaving its marginal and terminal deposits to form the conspicuous morainic features which we now behold.

The traces of the eastward march of this great glacier across the watershed between the basins of the Nairn and Findhorn have been pointed out in an earlier paragraph, and are also referred to in the Annual Summary for 1905 (p. 116).

r. Hinxman.

A number of interesting phenomena, additional to those described in last year's and former Reports, have been observed on both sides of Strathdearn in relation to the lateral drainage along the margins of the valley glacier at different levels, at a time when the natural flow down the hill sides into the Findhorn was blocked with ice.

The spurs that separate the side valleys on the south-east side of the river, between the Allt a' Mhuilinn and the Highland Railway, are cut through by two distinct series of deep rocky gullies or peat filled hollows, that in some cases debouch on to flat terraces of alluvial deposit. The lower

series can be traced, in a rude alignment, from the hill side ¾ mile S.E. of Dalmigavie to the north side of the Clune burn, the dry valley at the former locality being particularly conspicuous.

The levels of these cross-cuts fall gradually northward from about 1,600 ft. to a little below the 1,500 ft. contour line. The higher and less continuous series occupies positions ranging from nearly 2,000 to 1,700 feet.

An interesting example of reversal in the direction of marginal drainage is found on the upper side of the fir wood immediately south of Dalmigavie farm. Here there are two nearly parallel dry channels, the higher of which falls to the north, the other, a few yards further down the hillside, to the south.

The oscillation of the edge of the ice sheet, and the alternate predominance of the Findhorn and Spey glaciers along the present watershed between the valleys of the Upper Dulnan and the Findhorn, is shown by the series of dry overflow channels that cross the existing water-parting. A fine example is found at the head of the Allt Steallach, between the two Carn na Guailles. On the skyline, at a height of 2,000 ft., the well defined channel is 60 yards in width, filled with peat to a depth of 15 feet or more, and shallowing out to the west. On the east side of the watershed it deepens rapidly between abrupt rocky banks, and debouches on to a peat-covered alluvial flat above the present course of the Allt Steallach. The overflow has in this case evidently been from the Findhorn valley into that of the Upper Dulnan.

An overflow in the reverse direction is indicated by three channels which head up south-west to peat filled depressions on the watershed immediately east of Carn Coire na h' Easgainn, at a height slightly exceeding 2,300 ft. Further evidence of the position of the Spey ice is afforded by the well formed winding moraine, 400 yards in length, which forms the actual watershed along the summit of the southern Carn na Guaille. The side of the mound facing the Dulnan valley is markedly steeper than that to the west, and in addition to boulders of granitic and metamorphic rocks common to the whole district, there are several perched blocks of a peculiar quartz-felspar-porphyry, not known to occur within the Findhorn basin, but closely similar to the well known "Glen Tromie porphyry" of the Upper Spey valley. It is evident that this moraine was laid down at the edge of a glacier moving northwards out of Strathspey.

Two well marked overflow channels have also been observed on Carn Sgulain and Bruach nan Imirichean, crossing the watershed at heights respectively of 2,500 and 2,600 ft. In both these cases the flow has been eastwards into the head of the Dulnan valley. Mr. Anderso

In several places the valley of the Dulnan is constricted by the projection of lateral spurs, a feature which led to the heaping up of the ice against the opposing ridges, to the

steepening of the gradient of the marginal channels and to the erosion of rock-notches across the rock barriers. As an example may be cited the four rock gullies which cross the ridge that falls south-eastwards from Carn Airidhe nan Eag into the main valley. An extension of the same principle to the case of glaciers occupying adjacent parallel or slightly convergent valleys will account for the formation of channels across the intervening ridge. A difference in level between the two glaciers has caused a flow of water from that one which stood exactly at the height of any particular col down into the valley on the further side. Alternations in the relative height of the two glaciers would also produce overflow in contrary directions at different periods. Thus between the river Dulnan and its tributary the Allt Mor there are channels on the south of Carn Dulnan through which the water from the Dulnan valley poured into that of the Allt Mor, while to the north of the same hill the drainage process was reversed.

r.
arruthers. The whole area of the Upper Findhorn basin, as far as surveyed to the margin of the map, also abounds in marginal and overflow channels, ranging in size from shallow trenches along the hillside to rock gorges over 200 ft. in depth.

The finest examples are found in the neighbourhood of Coignafearn, where, on the north-west side of the main river valley, a series of marginal channels, increasing in size with the retreat of the glacier to the south, are displayed in great perfection. The first of these appears as a rock trench that runs obliquely down the hill-slope, half a mile S.W. of Coignafearn. A second and deeper channel follows the northern flank of the tributary glen of the Allt Odhar Mor for half a mile before falling into the main river valley, to which the third and largest channel is confined. Starting on the southern slopes of Carn Leachier Dubh, this last feature follows the hillside for a distance of a mile before it reaches the bottom of the Findhorn valley, and midway in its course cuts completely across the present large tributary valley of the Allt Odhar Mor.

Equally fine examples of marginal channels, one of which is nearly $1\frac{1}{4}$ mile in length, are seen on the south side of the main valley further to the south-west, and opposite to the ridge of Am Bathach.

Of the many overflow channels found in the district, attention may be directed to that one on the top of the Sith Mor, opposite Coignafearn, where the drainage from the main valley glacier, pouring over the south side of the hill into the wide basin of Coignashie, has cut a rock trench over 100 ft. in depth, the entrance to the trench being marked by a series of well defined terraces.

Mention may also be made of the great overflow channels which cross from the valley of the Allt Odhar Mor into Glen Mazeran, one of which, now only occupied by a tiny streamlet, is flanked by granite cliffs 200 ft. in height.

[redacted]son. In the extreme N.W. corner of the Sheet (74) two overflow

channels, deeply cut in the solid rock, cross the ridge between the Flichity Burn and Allt Beag in an E.N.E. direction.

*Timber.*—Small plantations of larch and fir have been made round the shooting lodges of Kyllachie, Glen Mazeran, and Dalmigavie. Natural birch wood clothes the steep northern slope of the Findhorn Glen as far up as Am Bathach, where the birch flourishes up to a height of nearly 2,000 feet, and a single beech tree was noted at Coignashie, 1,200 feet above sea-level. A characteristic feature of the Findhorn basin is the thick growth of juniper which covers the grassy slopes of the main valley and its tributaries, and extends up the hill burns wherever their banks are free from peat, almost to the watershed. Mr. Hinxm

*Peat.*—Almost the whole of the high ground towards the head of the Findhorn basin, between the north-west and south-east watersheds, may be said to be covered with hill peat, only the sides of the deeper valleys and a few of the higher hill tops being bare of this deposit. The average depth noted in section ranges from 4 to 10 ft., but probably reaches a considerably higher figure on some of the cols and hollows. One, and in some cases two, layers of *Pinus sylvestris* occur, the higher 2 or 3 ft. from the present surface; and a layer of *Betula alba* at or near the base.*

Fully one half of the upper basin of the Dulnan, above its junction with the Allt Fethlinn, is also covered with thick peat. The greatest thickness which has been observed is 12 ft., and it is evident that a great deal of the deposit exceeds 6 ft. in thickness. Mr. Ander

Close to the mouth of a small stream which joints the Dulnan about 2 miles north of Carn an Fhreiceadain, an interesting section has been observed. At the base are two and a half feet of peat containing some birch remains. Above this follows three feet of alluvial detritus deposited by the tributary stream, overlain by eight feet of peat, with three separate horizons containing the stems of juniper. The middle layer also contains some birch.

## *Caithness.*

The work carried on in Caithness (Sheets 109, 110) during the past year, included the completion of the Langwell Forest ground and the survey of the coast line from Ousdale to Dunbeath, and between Janetstown and Lybster.

The area examined by Dr. Crampton is occupied by rocks forming the lower part of the Caithness Flagstone Series, and by the ancient floor of crystalline schists and granites upon which they rest. The unbroken cliff line affords excellent sections, and the rocks are also exposed along the river courses Dr. Crampt

* For further notes on the flora of the Findhorn peat mosses, see a paper by Mr. F. J. Lewis, F.L.S., "The Plant Remains in the Scottish Peat Mosses." Part II., p. 346. *Trans. Roy. Soc., Edin.*, vol. xlv., 1906.

and smaller streams, but the ground inland is much obscured by the peat which covers nearly the whole of the plateau. The higher hills such as Scaraben, Small Mount and Creag Scalabsdale, emerge from this peat covered plateau, but are almost entirely buried in their own débris.

## HIGHLAND METAMORPHIC SERIES AND ASSOCIATED IGNEOUS ROCKS.

mpton. *Metamorphic Rocks.*—The strike of the metamorphic rocks of this district has an east and west trend. Rocks of the siliceous type of the Moine series and a pelitic gneiss with garnets are exposed over a wide belt to the south of Scaraben and also along the watershed to the west of Morven, where they are in continuation with the crystalline schists described elsewhere.* Quartz veins occur in these rocks west of Morven but no gold has been detected in them. The rocks to the west of Morven are locally decomposed to some depth, this being specially the case with the mica-schists, the large quartz veins standing out boldly above the rotted rock. The position of these rocks close to the Old Red Sandstone boundary suggests a comparatively recent removal of the overlying sediments.

The quartzite of Scaraben is a very pure, white, quartz-schist in which micas are very scarce. It follows two distinct lines of outcrop, forming the hills of Scaraben, Salvoich, Creag Scalabsdale, Small Mount, and Cnoc nan Eireannaich.

The mapping shows that one of these belts of quartzite is successively in contact with the siliceous schists and pelitic gneiss of the Moine Series, like the quartzite in the Kildonan area as previously mapped by Mr. Greenly. But apart from this relation, no direct evidence of unconformity, such as a conglomeratic base between the Scaraben quartzite and the other schistose rocks has been detected, and the nature of the passage between these groups indicates rather a conformable sequence.

*Igneous Rocks.*—Two small exposures of a rock identical in macroscopical appearance with the augen-gneiss of Inchbae, occur in the bed of the Berriedale River east of Braemore. One is in contact with the quartzite at the Fall pool, two miles below Braemore, but the junction-plane coincides with a line of movement which obscures the relation between the rocks. The nature of the rock and the character of the foliation show it to represent a granite which was intruded into the surrounding sediments, previous to the movements which simultaneously altered the former into an augen-gneiss and the latter into crystalline schists. The second exposure forms an inlier in the Old Red Sandstone deposits. A considerably larger outcrop of a similar rock has been previously mapped near Corriechoich west of Braemore.

* Annual Report, 1896, p. 17; Summary of Progress, 1897, p. 44; Summary of Progress, 1898, p. 18.

Two granites of later date cover wide areas in this district and have been referred to in former Reports. Of these the Ord granite, whose northern boundary has been traced from the watershed across the Langwell and Berriedale waters to the coast at Badsallach, is a pink granite frequently showing large porphyritic felspars. The other or Strath Halladale granite has a wide extension in the ground to the north and occupies much of the country west of Morven. It is grey in colour and has associated with it many later veins, some of which show a pegmatitic structure with graphic intergrowths of quartz and felspar. These two granites are nowhere seen in conjunction, but evidently both belong to a period of intrusion later than the movements which produced the foliation of the surrounding schists. Both had also suffered marked erosion prior to the deposition of the Old Red Sandstone of Caithness. Great interest is attached to the relations between these granites and the crystalline schists of this region, and the question has been discussed at some length by Messrs. Horne and Greenly and others in former Reports.* Over wide areas the granites and schists are so closely intermingled that it is difficult to draw any accurate line of demarcation between them. In the case of the Ord granite this feature is more of a marginal phenomenon, but in the northern intrusion is almost regional in character and affects many miles of country. Throughout this complex included bands and lenticles of crystalline schists preserve their normal strike and relations.

Three distinct types of intrusion of the igneous rock can be recognised. (1) Rupture of the crystalline schists, the angular fragments forming a breccia surrounded by granitic material. This structure appears to be restricted to the bands of more siliceous granulite. Degrees of permeation and absorption of the schist fragments by the igneous magma can be recognised. (2) '*Lit-par-lit*' intrusion, the granitic material penetrating in bands and thin folia between the foliation planes of the schists. This type is most frequent in association with the mica-schists. (3) Veins of granite and pegmatite that cut the schists and also the granite in various directions without any definite orientation and follow lines of fracture. Except in the last mentioned case the junction line of the igneous material with the schist is often very indefinite, and shows no evidence of chilled margins to the granite. The crystalline schists further appear to be so permeated by the igneous magma that they pass gradually from rocks showing granulitic structure into granitoid gneisses and granites in which a pseudo-foliation due to the last remaining traces of the planes of schistosity of the crystalline schists can sometimes be detected.

* Annual Reports, 1893, p. 264; 1896, p. 17; Summary of Progress, 1898, p. 18. Horne and Greenly, *Q. J. Geol. Soc.*, 1896, vol. lii., p. 633. See also Hinxman, Explanation of Sheet 76, p. 11, 1890; and a recent paper by Sederholm, "Om Granit och Gneis." Bulletin de la Commission Geologique de Finlande, 1907.

## OLD RED SANDSTONE.

rampton. The order of succession of the strata of Old Red Sandstone age south of Berriedale in Caithness, which was established by Sir A. Geikie,* has been confirmed in the course of the geological survey of the district. The basement beds of arkose, which rest on the granite near Ousdale, are followed in upward succession along the coast by (1) 700 ft. of chocolate-coloured and purple beds, chiefly mudstones; (2) the curious breccia of Badbae with a thickness of about 200 ft., and lastly by (3) over 2,000 ft. of close-textured red sandstones and coarse flagstones constituting the Berriedale sandstone group. Between Berriedale and Badsallach, ¾ mile further north along the coast, the beds are faulted and the dip is reversed, bringing up from beneath the sandstones bands of conglomerate forming a local base and resting on granite and schist. This conglomeratic base, which probably represents the horizon of the Badbae breccia, continues inland, crossing the Berriedale water about a mile from the sea. The boundary line of the Old Red Sandstone is defined further west by a line of fault which strikes inland from the coast about ¼ mile north of Berriedale water and truncates in succession the sandstone group, the Badbae breccia, the mudstones and the basement conglomerate. The Old Red Sandstone of the Berriedale and Ousdale area is therefrom completely separated from the deposits of the same age further to the north. The granite and schist occupy the coast line for a distance of one third of a mile north from Badsallach until conglomerates are again encountered, but dipping in a different direction, to the N.E. This conglomerate, which forms the headland of Ceann Leathad nam Bo, probably occupies a somewhat similar horizon to that of the Badbae breccia further south. The section northwards along the coast of Dunbeath is a gently ascending one, the conglomerates being succeeded by 700 ft. of close-textured red sandstones, followed by alternations of mudstones, sandstone and coarse flagstones as far as Sithean Dubh. These rocks, like those south of Berriedale, have as yet proved unfossiliferous, and may be included in the Berriedale sandstone group. Between Sithean Dubh and Dunbeath the deposits lose their predominating red colour, and present a succession of hard, grey, close-textured sandstones, dark shales, coarse dark flags, and thin impure limestones, the whole bearing a strong resemblance to the beds of the Wick group further to the north. Fragments of fossil fish were observed in one of the limestone bands in the Dunbeath water. From the local base at Badsallach, the conglomerate resting on the crystalline rocks has been traced inland east of the Berriedale water to Burg Ruadh, where its direction changes

* "The Old Red Sandstone of Western Europe." *Trans. Roy. Soc. Edin.*, vol. xxviii, p. 374.

abruptly to the west, and crossing the Berriedale water, continues along the lower slopes of the north flank of Scaraben. Isolated patches of conglomerate, consisting entirely of cemented fragments of the white Scaraben quartzite, occur higher up the slopes, showing that the Scaraben ridge formed a steep shore line on to which the Old Red Sandstone deposits overlapped. These conglomerates on the flanks of Scaraben represent successive horizons which, further from the shore, consist of sandstones and mudstones. At one horizon, about 700 ft. above the base, conglomeratic deposits extend to a greater distance and can be followed along the strike across the Dunbeath water to Cnocan Con na Creige, representing a great shingle bank overlying sandy and muddy deposits. The outliers on Morven, Smean, and Maiden Pap, further to the west, are probably remnants of this higher conglomerate. West of the outcrop of the higher conglomerate purple and red mudstones and sandstones extend in a W.S.W. direction in a long tongue towards the boundary between Caithness and Sutherland. The local base in this area is a coarse conglomerate, but elsewhere the mudstones and sandstones rest directly upon the crystalline rocks, or are faulted against them. The rocks overlying the conglomerate of Cnocan Con na Creige can be seen in the Dunbeath water. They here consist of red sandstones and coarse flagstones similar to those on the coast section south of Sithean Dubh, and pass upwards into the calcareous flagstone group of Dunbeath, along a line extending from Sithean Dubh inland to Cnoc na Maranaich, and crossing the Dunbeath water about half a mile below Ballantrath. The sequence established in this area corresponds with that proposed in the area further north,* except that a higher conglomerate horizon is not met with in the latter region. The conglomerate of this area affords many interesting features, some of which have already been referred to in former reports and elsewhere.† Among these is the strictly local origin of the arkose at the base in the Ousdale area. This arkose passes into an angular breccia with schist fragments immediately beyond the limits of the granite outcrop. A similar local derivation of the fragments is found in the Braemore district, in places where the conglomerate rests directly on granite, quartzite, or augen gneiss, though this is by no means universal. The occurrence of fragments of augen gneiss in the conglomerates on the east end of Scaraben and on Achnahoish hill, indicate a carry of the material from west to east. The Upper or Badbae breccia consists of fragments of schist and granite in an arkose matrix. The junction of this breccia with the underlying mudstones is well exposed in the cliff section at Badbae, and also on the north bank of the Langwell water, 1¼ miles above Langwell House, where the breccia contains small fragments of sandstone in

* Summary of Progress, 1897, p. 93.

† Summary of Progress, 1897, p. 93; 1898, p. 66; "Old Red Sandstone of Western Europe." *Trans. Roy. Soc., Edin.*, vol. xxviii., p. 369.

addition to those of schist and granite. At both these localities the mudstones appear to dip at a higher angle than the overlying conglomerate, the base line of which apparently truncates the beds below. At Cnocan Con na Creige the appearance of unconformity between the conglomerate and the underlying red mudstones is even better marked. In this connection the occurrence of slabs of sandstone in the conglomerates of Smean, noted by Sir A. Geikie and Mr. Pocock, is of importance.*

The conglomerates to the north of Cnocan Con na Creige and at Sarclet have yet to be surveyed, and may throw further light upon this interesting point.

The tracing of the base of the Old Red Sandstone in this region proves that here, as elsewhere, the floor upon which the sediments were laid down was highly uneven.

The other quartzite hills, Creag Scarabsdale and Small Mount, add their testimony to that of Scaraben, and a small inlier of granite appears among the Old Red Sandstone deposits a mile west of Cnocan Con na Creige, a considerable distance within their boundary.

rruthers.

*Lybster to Janetstown.*—Results of considerable interest have attended the preliminary survey of the coast section from Janetstown Harbour to Lybster Bay. Instead of affording, as was previously supposed, a continuous downward succession through the lower part of the Caithness flags, there is every reason to believe that a large fault, running in a S.W. direction immediately to the south of Latheron, and seen in the cliff section $\frac{1}{4}$ mile east of Janetstown Harbour, brings down on its easterly side a series lying comparatively high up in the Caithness flagstones, between the Wick flags and the John o' Groats Sandstones.†

The presence of these higher beds in the coast section was first suggested by the discovery of fragments of *Coccosteus* in a thick series of thin-bedded dark flags, much resembling those of Noss Head, and overlain by a series of fossiliferous flags, lithologically identical with the Spital flags, and showing the same characteristic pale blue weathering. These are succeeded by a remarkable group of variegated red and yellow concretionary sandstones, bearing a strong resemblance to those occurring in the Castle Sinclair group at Ackergill, a point confirmed by Dr. Crampton, who further found in these beds black bituminous shales, also closely resembling those seen at Ackergill in association with the sandstones.

As the series has yet to be thoroughly searched for fossils, no details can at present be given of the palæontological sequence, although attention may be drawn to the abundance of *Coccosteus*, a fossil so strikingly absent from the lower part of the Caithness flagstones.

* "Old Red Sandstone of Western Europe." Summary of Progress, 1898, 86.

† For the position of these beds, and those also mentioned in the succeeding paragraph, see Summary of Progress, 1906, p. 86.

South-west of Janetstown Harbour, a gently ascending sequence, consisting mainly of calcareous sandstone, with some layers of shale and at least one limestone with fish remains, occupies the coast for about half a mile. This series is then cut off by what is probably a continuation or branch of the large fault met with north-east of the harbour, which bends round and passes inland again, bringing in beds on the south side that are probably on a much higher horizon. Mr. Anderson.

Following the succession inland from the harbour, we pass through a considerable thickness of beds in which grey calcareous sandstone like that seen near the harbour plays a prominent part, though shale and limestone are by no means absent. The relative position of the beds is not affected for some distance by any large faults, but the absence of continuous sections makes it difficult to estimate thickness or construct a complete section. Ascending the Latheronwheel burn we pass gradually into higher strata as far as the bridge on the high road; beyond which point the strata dip north-east towards a syncline or elongated pericline, whose centre corresponds with the hill of Leodebost. Starting afresh on the south-east side of the pericline, at a horizon not much above the rocks at the bridge, we can trace an upward succession towards the centre. This contains among other strata, two horizons of shale with impure limestone, and two massive sandstones.

The lower limestone horizon has been traced for some miles further to the east and north, by Mr. Carruthers.

To the north of a line of disturbance which runs from Latheron hospital to near Braehungay, a dominant sandstone facies still continues.

## PLEISTOCENE AND RECENT.

Over the greater part of the plateau, and at high elevations, the drift is very thin or entirely absent. At lower levels all inequalities of the surface were at the glacial period masked with drift, while the deep pre-glacial channels of the Berriedale, Langwell, and Dunbeath Waters were choked with boulder clay. These have since been partly re-excavated by the rivers, and their original rocky walls again laid bare for considerable distances. Where these channels run east and west, the exposure of the wall has chiefly taken place on the north side, a fact probably connected with the form impressed on the surface of the boulder clay filling the channels by the ice moving from south to north. A fine example of a post-glacial rock gorge occurs on the Dunbeath Water about ¼ mile above Ballantrath, the earlier pre-glacial channel, filled with boulder clay, being seen close by. The Chlais Mhor, a deep dry gully in the drift on the north side of a hill south of the Dunbeath water four miles above its mouth, has been cut by glacial drainage at a time when the ice was retreating from the country. Dr. Crampto

Between Scaraben and the watershed of the Langwell to the south, the general movement of the ice, as shown by striæ, was E.S.E., but near the coast, at Badbae, a deflection to E.N.E. occurred, further north, at Beinn Choireach, due north, and from Chlais Cairn Hill to Achnachyth, the direction was N.N.W.* These movements are confirmed by the carry of the drift material and boulders. Fragments of Jurassic rocks with Ammonites were obtained some years ago in the boulder clay of a river terrace at Berriedale village. A line drawn from Berriedale to Achnaclyth approximately separates the shelly boulder clay on the east from the hard sandy boulder clay derived from the rocks inland. The latter contains numerous blocks and smaller fragments of granite and schist, but differs locally in colour, according to the rocks from which it has been chiefly derived. Boulders of conglomerate have also been carried eastward along the south flank of Scaraben. The shelly boulder clay contains numerous fragments of Old Red Sandstone rocks, with fewer examples of the crystalline schists, and is similar in all respects to the well known shelly boulder clay of Caithness described in former reports. Shells were detected in the boulder clay sections all along the Dunbeath water.

Moraine-like mounds occur along the course of the Langwell Water from a point below Wag to within three miles of the sea, and again on both sides of the Berriedale water above An Dun. In the latter case, the morainic material must have been deposited on the boulder clay that filled the channel of the Berriedale water before the latter was re-excavated by the stream. A line of moraines also flanks the eastern side of Beinn Choireach and extends northwards from Newport for a distance of more than a mile.

nderson. The general direction of the ice movement in the country inland from Latheron and Janetstown was from 10° to 45° west of north. The coincidence of this direction with the general strike of the rocks renders it difficult to distinguish between strike features and those due to glaciation. One or two instances of rock hollows were, however, observed, which are evidently due to glacial grooving. The thick deposits of shelly boulder clay are confined to the course of the Latheron-wheel burn and to a narrow strip along the coast. The erratic blocks observed consist mainly of Old Red Sandstone rocks, but also include some fragments of Jurassic sandstone and others of schist and granite.

rampton. In the numerous good sections met with in the peat of this area a layer containing birch is found widely distributed, and usually at about one foot or more above the base. Hazel nuts are sometimes abundant in this layer, and nearly all the specimens found had been gnawed and emptied by some small rodent.

* "Glaciation of Caithness." Peach and Horne, *Proc. R. Phys. Soc. Ed.* 1881, vol. 6. Summary of Progress, 1897, p. 151; 1898, p. 178.

At the base a layer containing species of *Salix* is also widely distributed. Specimens of this peat from the Feithe Chaoruinn Bheag, about one mile west from Cuperniesgaich, were submitted for examination to Mr. Lewis, of Liverpool University, who has recently been studying the flora buried in peat in the Highlands. He reports that "the general character of the material is much like that of some of the sub-arctic zones lying above the *Salix reticulata* zone in the Highland peat mosses." Amongst other species he reports the presence of a species of *Carex*, and says concerning it: "If my determination of *Carex frigida* is right, its presence here is interesting as it now occurs (in Britain) only on ground about 3,000 feet in Aberdeenshire. It is not an arctic (Scandinavian) plant, but has a high Alpine distribution in Central Europe."

While mapping in Caithness, opportunity was taken by Dr. Crampton of studying the plant associations in relation to superficial deposits and drainage. Observations were made regarding the effects of drainage on the peat, the factors controlling the spread or decay of the natural woods, the plantations, and the more common weeds of the cultivated ground. The value of such field observations in their bearing on the economic development of the country is obvious, and publication of the results of this work will follow in due course.

## 3.—Airdrie and Shotts District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A. } Geologists.
Mr. E. B. Bailey, B.A. }

### VOLCANIC ROCKS OF THE CALCIFEROUS SANDSTONE SERIES TOGETHER WITH THE ASSOCIATED SEDIMENTS.

*Campsie Fells.*—The season's work has confirmed Dr. Peach's Mr. Baile original interpretation of the remarkable sigmoid twist taken by the great Campsie fault where it passes to the north of Kilsyth. In the area included within this sudden outward bend the base of the lava group of the Fells is well exposed. As was first shown by Dr. Peach, the horizon upon which the main mass of volcanic rocks here reposes is considerably lower than in the type sections of Ballagan to the west, or of Fintry to the north. In fact, the great Cementstone Group is almost unrepresented at Kilsyth, and the volcanic sequence comes on in force a few feet above the summit of the Cornstone Group of the Upper Old Red Sandstone Series.* But a markedly different group of lavas occurs here at the base from that which forms the lowest division in the western part of the Campsie

* This series was mapped out by itself in the original survey, though described as part of the Calciferous Sandstone Series in the Explanation of Sheet 31, pp. 14, 15 (1879).

Fells. It is an earlier group among which Markle basalts (a macroporphyritic type) figure prominently. The basement division of the west consists, on the other hand, entirely of Jedburgh basalts (a microporphyritic type). In the west the succession is:—

(*d*) Upper Group with several Markle Basalts and Mugearites.
(*c*) Lower Group consisting of Jedburgh Basalts.
(*b*) Cementstone Group.
(*a*) Cornstone Group (Upper Old Red Sandstone).

In the hill-face to the north-west of Kilsyth, the succession is:—

($d^1$) Upper Group characterised by Markle Basalts.
($c^1$) Lower Group of Jedburgh Basalts.
($b^1$) Still Lower Group characterised by several Markle Basalts.
($a^1$) Cornstone Group (Upper Old Red Sandstone).

Slightly further to the east, the great Jedburgh basalt group, which, in a westerly direction, has been followed continuously for a dozen miles, thins away completely and the two macroporphyritic series come together.

The evidence just described favours the interpretation (1) that the Campsie plateau has been built up through the interlocking of numerous distinct cones; (2) that the lava succession, established in any particular area, does not, as had been thought probable from the more restricted observations of previous years, indicate a differentiation sequence for the whole district; (3) that throughout the long period, during which igneous activity prevailed, there were neighbouring centres, and groups of centres, each more or less true to its own type of ejectamenta, and each maintaining independently an intermittent discharge. One set of centres would be stirred to activity before another, and the periods of repose and extinction would differ in individual cases. It is obvious that a centre supplying Markle basalts originated in the neighbourhood of Kilsyth at a time when the shales and cementstones of the west were being laid down, untroubled by any volcanic disturbance. Then were opened the great series of necks which lie between Dumgoyn and Fintry, every one pouring forth basalts of the Jedburgh type and together building up a wide plateau, the base of which rests in the west upon the Spout of Ballagan sandstone, while in the east it extends some way southward on to the early Kilsyth lavas. This complex group of interdigitating cones, gathered about the various Dumgoyn centres, was in turn wholly or in part covered by fresh outpourings of lava, chiefly of the Markle type, which appear to have been supplied in some measure from the old Kilsyth focus reawakened.

## COAL MEASURES.

Messrs. Clough an Wright.

The Carboniferous rocks in the area revised near Airdrie extend from the Upper Drumgray seam to a few hundred feet above the Upper Coal of Glasgow. Owing to the present high price of coal a number of shallow pits have recently been sunk or re-opened, to take out small patches of coal which had been left, or to split old "stoops." Increased attention is also being given to thin seams which were formerly neglected, or to seams somewhat damaged by "burning."

The Lady Grange coal is being worked in No. 5 Pit, Monkland Colliery, and is there a fair coal about two feet thick, but with a three-inch band of "sclit" which is difficult to separate. This coal is exposed in the Monkland Glen on the upthrow or north-eastern side of a small fault, and is separated from the overlying Virtuewell seam by some shale and a thick bed of sandstone, which forms most of the crags in this picturesque glen.

In a streamlet about 400 yards east of Dalmacouther farm various nodules of limestone, embedded in fireclay, are of interest from their richness in *Naiadites*. They appear to be about ten feet above the Virtuewell seam, and perhaps represent the Roughband ironstone of Newarthill and Cleland. Limestone, in much the same geological position, has also been proved by several bores considerably east of this locality. The journal of a bore put down 1,000 yds. N.N.E. of Dykehead farm, records the following section;—

| | Ft. | in. |
|---|---|---|
| Fireclay ... ... ... ... ... | 0 | 8 |
| Hard limy rib ... ... ... ... | 0 | 4 |
| Fireclay ... ... ... ... ... | 2 | 6 |
| Hard limy rib ... ... ... ... | 0 | 6 |
| Fireclay ... ... ... ... ... | 0 | 10 |
| Hard limy rib ... ... ... ... | 0 | 4 |
| Grey fakes ... ... ... ... ... | 5 | 1 |
| Sandstone ... ... ... ... ... | 4 | 6 |
| Blaes... ... ... ... ... ... | 0 | 7 |
| Virtuewell Coal. | | |

Another bore still further away, about 900 yds. north-west of Plains Station, passed through two thin limestones, in and separated by fireclay, the bottom one being 14 ft. above the top of the Virtuewell coal. A third bore, the position of which we do not know except that it is near Meadowhead, passed through a limy ball, overlying fireclay, about 21 ft. above the Virtuewell seam.

Mr. Clou

The Musselband coal, which lies about 30 ft. above the Airdrie Blackband ironstone, is well exposed at the east side of the burn about 300 yds. east of Dykehead farm. It is, as usual, divided into two "leaves," each being about 2 ft. thick. The Musselband ironstone is also exposed above the coal, in a partially decalcified condition, but very rich in casts of bivalves, among which is that of *Anthracomya adamsi*. Dr. Wheelton Hind, who determined the specimens, states that this consti-

tutes the first record of this fossil in the Coal-measures north of the Tweed. Lower down the same burn the Musselband coal is seen again and again, owing partly to faults and partly to the general southerly dip, but it is always badly burnt by a whin sill which occurs a little below the top. The overlying Virgin and Splint coals, with only a few feet of fireclay between them, are exposed on the west side of the burn about 700 yds. N.N.E. of Rawyards Station, but also in a somewhat "burnt" condition.

The railway cutting a quarter of a mile north-east of Cairnhill, shows the following section of the Virgin Coal with roof and pavement:—

| | Ft. | in. |
|---|---|---|
| Sandstone ... ... ... ... ... | | |
| Coal ... ... ... ... ... ... | 0 | 10 |
| Coal and dirt ... ... ... ... | 0 | 6 |
| Clay ... ... ... ... ... ... | 0 | 6 |
| Coal ... ... ... ... ... ... | 1 | 2 |
| Shale... ... ... ... ... ... | 0 | 6 |
| Coal ... ... ... ... ... ... | 1 | 2 |
| Shale... ... ... ... ... ... | 0 | 6 |
| Coal ... ... ... ... ... ... | 0 | 4 |
| Fireclay ... ... ... ... ... | 1 | 0 |

The Virgin seam was formerly worked a few hundred yards west of this locality, but a recent bore on the east side of the canal, a quarter of a mile W.S.W. of Cairnhill, showed it to be unworkable there.

Wright. The Upper Coal of Glasgow which is not known to occur elsewhere in the coalfields north-east of Airdrie, was wrought to a slight extent at Stanrigg, in the year 1850. The coal here lay immediately on the surface, the boulder clay forming the roof of the workings. According to Mr. James Prentice* it was of fair quality and had a thickness of 2 ft. 3 ins.

Clough. A coal formerly worked a little at the crop nearly a quarter of a mile west of Peterburn, is probably slightly lower than the Upper Coal of Glasgow. The section a few feet below shows considerable lenticles of limestone with well developed cone-in-cone structure and below these a musselband.

The coal near the east side of the Calder about a quarter of a mile W.N.W. of Palacecraig is the Upper Coal of Glasgow. It is not less than two feet thick, but the lower part is a good deal mixed with dirt. The roof consists of shale with ironstone courses and "mussels." Rather more than a quarter of a mile south of this coal-crop, and in stratigraphical position probably about 250 ft. above it, is a marine band, the lower part composed of a somewhat hard blaes, two inches thick, and the upper of a dark grey impure ferruginous limestone, six inches thick. From the fossils collected from

* *Trans. Fed. Inst. of Min. Engrs.*, vol. xii., p. 435 (1897).

this band by Mr. Tait, the following list has been provisionally drawn up:—

*Lingula squamiformis* Phill.
*Orthoceras*, indet.
*Goniatite*, indet.
*Posidoniella sulcata* Hind.
*Pterinopecten papyraceus* (J. Sow).
*Productus*, indet.

Lithologically, this bed is very similar to marine bands which have already been found by various workers, near the base of the Upper Red Barren Measures in several of the other Scottish Coalfields, and it seems probable that it is on the same horizon. Some further account of the Palacecraig bed, and of the other marine beds referred to, is given in the Appendix.

## INTRUSIVE ROCKS IN THE COAL MEASURES.

Messrs. Clough and Wright.

The sheets of intrusive dolerite (whin sills) a little north and north-east of Airdrie, occur on different stratigraphical horizons and are generally found in lower positions towards the north. Occasionally, they change their horizons suddenly, as is well seen in Raebog Colliery, where a sheet of "white horse" (white trap) which, at the shaft bottom and for a little distance north, is nearly flat and just above the Kiltongue coal, suddenly takes a steep inclination, of about 45°, to the north-west and cuts sharply through the strata.

In petrological character these sheets seem all of much the same type, the three which have been sliced and examined microscopically, by Dr. Flett and Mr. Bailey, being all classed as quartz dolerites.

Mr. Clough.

The sheet which was formerly quarried near West Craigneuk farm is now known to be in a position slightly above the Humph coal. The small patch in the river Calder near the head of Monkland glen is in a considerably lower position—about twelve feet below the Kiltongue Musselband. A sheet in much the same position has been met with in the adjoining workings of No. 6 Pit, Monkland Colliery.

## PLEISTOCENE.

Mr. Bailey.

*Campsie Fells.*—The overriding of the Campsie Fells by Highland ice has long been a familiar fact. At a later stage local glaciers lay in the shelter of the northern cliffs, and bore out from them numerous basaltic boulders in a direction completely at variance to the main carry of the drift. In places too, as in the Corrie of Balglas, they built up well defined terminal moraines. That this local glaciation marked a phase in the retreat of the main ice-sheet may be inferred with considerable probability from the fact that no trace of

marginal drainage phenomena has been discovered along the northern face of the hills. It is obvious that a district which retains local glaciers, on the withdrawal of an invading ice-sheet, will thereby be wholly or in large measure protected from the ravages of marginal drainage.*

Messrs. Clough and Wright.

The drift near Airdrie consists chiefly of a stiff dark brown or dark grey boulder clay which often forms conspicuous "drums" striking somewhat north of east, nearly parallel to the glacial striæ. Occasional beds of sand and gravel are seen below boulder clay, as, for instance, on the north side of the river Calder about 600 yds. S.S.W. of Palacecraig, and in another place 100 yds. west of Monkland House. In the former locality the beds are almost vertical and crossed by several small gently inclined faults, on the upper sides of each of which the beds have been moved a few inches eastward past the faulted ends of the corresponding beds on the lower sides. It seems clear that the steep position and the small faults are alike due to glacial disturbance.

Mr. Clough.

The sand, 100 yds. west of Monkland House, is also very steep in part. Though it underlies boulder clay it must be regarded as glacial or inter-glacial rather than pre-glacial, as it contains pieces of chert and other rocks which must have been derived from far distant sources. It is, perhaps, connected with beds of sand and gravel which have been met with a little further north-east, in parts of the Monkland Colliery workings on the north-west side of Monkland glen. These parts cannot now be examined, but it seems probable that the beds referred to occur in an old river course, striking north-east and south-west, which in the position of the Virtuewell coal had a breadth of 60 or 70 yds. They are covered by boulder clay, as is proved by a boring and also by the character of the overlying ground surface.

A bore put down a few years ago by the Monkland Colliery Co., about 300 yds. E.S.E. of West Craigneuk, went through a stripe of moss, about 18 ins. thick, lying below 30 ft. of boulder clay and above more boulder clay. As it was clear from the gentle inclination of the ground that no appreciable amount of slipping could have taken place here, a second bore was put down by Mr. Clough in order to get a sample of the peat for botanical examination. The new bore was started two feet from the old one but only went through four inches of moss. This rapid variation in thickness probably indicates that the moss is part of a torn fragment which had been carried some distance in much the same way as the boulders in the clay. Mr. F. J. Lewis, of Liverpool University, has examined the samples obtained and reported as follows:—

"Much of the material consisted of undeterminable plant débris, but by careful washing a number of mosses and a few phanerogams were obtained.

* Messrs. Kendall and Bailey, "The Glaciation of East Lothian, South of the Garleton Hills." *Trans. Roy. Soc. Edin.*, vol. xlvi., p. 20, 1907.

"The phanerogams were as follows:—

*Betula nana*, L.? A small leaf rather fragmentary
Carex sp. One specimen.
*Potentilla Comarum*, L. Several small stems.
Salix sp. A few small flattened stems of a creeping willow.

"The mosses I sent to Mr. W. H. Dixon, M.A., F.L.S., who kindly undertook the labour of their determination.

'He reports as follows:—

'*Aulacomnium palustre*, Schwaeg. In some quantity though very fragmentary.

'*Cinclidium stygium*, Sw. A fragment merely of a leaf, but there can be no doubt about it. The red colour is perfectly preserved.

'*Anomodon Viticulosus*, Hook & Tayl. A single fragment of the upper part of a leaf. It cannot admit of doubt, although it is not at all a plant one would expect to find in this association.

'*Thudium Blandovii*, B. & S. Several undoubted fragments of stems and individual leaves.

'*Camptothecium nitens*, Schp. The preponderating plant.

'*Hypnum exannulatum*, var. brachydictyon, Ren. A few fragments of branches and leaves, showing the characteristic aerolation.

'*Hypnum straminium*, Dicks. A good deal of the material belonged here.

'*Aneura latifrons*, Lindb.? A fragment of a Hepatic which Mr. S. M. Macvicar has kindly examined for me.

He writes:—"It is one of the anacrogynous Jungermanniaceæ and is probably *Aneura latifrons*. The habitat being a peat moss supports this view, as it is one of the few thalloid species which are found in wet places in North Europe."

'The majority of the above species are what one would look to find in a peat bog under conditions that might be either temperate or sub-arctic. This would, in fact, apply to all with the sole exception of *Anomodon viticulosus*. They would, for instance (with that exception), all be likely to occur in any Scandinavian bog even into quite arctic regions. *Thudium Blandovii* is especially interesting, as it does not exist as a recent plant in Scotland, nor is it recorded for more than four localities (confined to two counties) in England, in most of which it is now probably extinct. It occupies the northern region of Europe, Asia and North America, not reaching into France, nor further south than central Germany and is distinctly a boreal type.

'The presence of *Anomodon viticulosus* is difficult to explain. It is a plant of lowland temperate regions, not reaching, as a rule, very high latitudes and extending as far south as the Canaries. It is never a bog plant, but is principally rupestral and arboreal, less frequently terrestrial. It may, of course, in this case be wind borne, though a more probable explanation would be that it was carried down a stream from a riparian habitat to the spot where found. It is perhaps scarcely safe to base such a deduction from the minute fragment of a single leaf of a moss, but so far as it goes it would certainly seem to indicate that the conditions favourable to the bog species found were not extensive, or at least not universal.

'As regards these bog species, however, I think their character, and the collocation of what must be considered for the amount of material a rather large number of species, all of one type, points to a true peat bog formation; not to a small patch of humus formed on a moraine covered glacier.

"The phanerogams, although few in number, certainly support Mr. Dixon's suggestion that the material represents a fragment of a Pleistocene peat bog. Whether the material grew *in situ* or was caught up by the glaciers which formed the upper boulder clay it is impossible to say, until the opportunity presents itself of either sinking a small shaft or putting down a number of borings in the locality. The plants certainly suggest that considerable areas of the country were free from ice at that time, and the type of association is hardly that which would be likely to exist during the maximum stages of glaciation."

It may be recalled that in the Faskine brick pit, rather more than a mile and a half south-west of the Monkland bore alluded to, Mr. James Bennie described some years ago the occurrence of peat within boulder clay.* Mr. R. Dunlop, also has described a bed of peat in boulder clay at a quarry near Burnhead farm, Airdrie.†

## ECONOMICS.

essrs. ough and right.

The present recrudescence of mining activity in the Airdrie district is no doubt of a temporary nature, and unless the Lower coals—those in the Carboniferous Limestone Series—are proved to be worth sinking to, we must anticipate a continued decline in the coal production of this district. The Burnlip diamond bore, which Messrs. Wm. Baird & Co., Ltd., started in 1906,‡ was completed during the summer, but the result was not satisfactory, there being considerable doubt about the interpretation of the lower part of the section. The same firm is now proceeding with another deep diamond bore, in a position about 150 yds. east of Haggmuir, about two miles north of Coatbridge, and it is hoped that more decisive evidence regarding the character of the Carboniferous Limestone coals will there be obtained.

r. Clough.

A bore put down in 1880 about 1,000 yds. N.N.E. of Dykehead was carried 82 fms. below the Kiltongue coal, but beneath this seam it met with only one coal—the Upper Drumgray—which exceeded eight inches in thickness. Another old bore put down 45 fms. below the Kiltongue coal in No. 5 Pit, Rawyards, met with an 18-in. coal at a depth of 24 fms., and a thinner seam 11½ ins. thick, at 30 fms., but below the latter no coal exceeded six inches. An ironstone, two feet

* "The Occurrence of Peat with Arctic Plants in Boulder Clay, at Faskine, near Airdrie, Lanarkshire." *Trans. Geol. Soc. Glasgow*, vol. x., p. 148, 1894.

† "Note on a section of Boulder Clay containing a Bed of Peat." *Trans. Geol. Soc., Glasgow*, vol. viii., p. 312, 1888.

‡ Summary of Progress for 1906, p. 92.

thick, called the Slatyband, was found at 40 fms. The coal at 24 fms. is probably the same as the "Balmoral Seam" of Gartsherrie Colliery and Drumpellier. The seam at 30 fms. is underlain by a "shaly blaes,"* six inches thick, and a bed of coal and blaes 11 ins. thick, and was correlated with the Shotts gas coal. In a bore in the School Pit, Rawyards, a 17-in. coal, at a depth of 25 fms. beneath the Kiltongue seam, is also probably the Balmoral seam of Gartsherrie Colliery.

In the Monkland Colliery the Lower Drumgray coal was a very good house coal from 21 to 33 ins. thick, the Balmoral, about ten fathoms lower down, was from 14 to 18 ins. thick, but was not worked, being poor in quality and with a bad roof. The Lower Drumgray coal has also been extensively worked near Cairnhill and Calder.

A number of whinstone (dolerite) quarries are being worked and supply a considerable amount of material, in the form of kerbs, setts and road metal, to Glasgow and the neighbouring district. Some of the quarries are said to have been working more than 100 years ago, and it is interesting to learn that in the early days of railways, "sleepers", of a shape different from those now in use, were often made of whinstone. Some of the old discarded "sleepers," perhaps 2 ft. by 1½ ft. by 9 ins., are still lying at the east side of the Coatbridge and Slamannan line, about 700 yds. N.N.E. of Rawyards Station.† Messrs. Clough and Wright.

In the brick works the material chiefly used is boulder clay. This is cleared of the larger and harder stones, and then ground up together with some blaes and fireclay, most of which are obtained from neighbouring waste heaps. One firm, the Calder Brick Co., Whifflet, make only a special class of brick for the construction of the linings, &c., of blast furnaces; the fireclay used is said to be all brought from near Salsburgh, but its geological position is not yet known.

## 4.—Carron and Slamannan District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. J. S. Grant Wilson.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers.
} Geologists.

Acknowledgment must be made, as in former years, of the valuable information supplied by mining engineers, colliery proprietors and others. Among these, the thanks of the staff are especially due to the Glenboig Union Fireclay Co.; Messrs. James Nimmo & Co.; the Callendar, Slamannan, and Darngavil Coal Companies; the United Collieries; and the Bonnybridge Fireclay Companies.

* As used in Scottish mining, the word "shale" means oil-shale.
† These were kindly pointed out by Mr. R. Dunlop.

## CARBONIFEROUS LIMESTONE.

Hinxman. *Cumbernauld District.*—The Calmy Limestone, together with the Hirst Coals which almost immediately underlie it, is exposed on the crest of a small anticline in the deep ravine cut by the Castlecary Burn, between the ruins of the Castle and the north end of the tunnel on the Caledonian Railway. The anticline is cut off at either end by a fault, and the limestone does not appear again on the south side.

A modification in the representation of the outcrop of the same limestone band has been made on the County March to the west of Luggiebank. The powerful fault which follows the line of the dolerite dyke westwards to Wester Glentore, three miles S.S.E. of Cumbernauld, leaves that intrusion near Fedderland, and crossing the Luggie Water in the neighbourhood of Blairlinn, shifts the outcrop of the Calmy Limestone westwards to near Grayshill, a distance of $2\frac{1}{2}$ miles. The amount of lateral displacement may be partly accounted for by the undulating arrangement and low angle of the strata.

The Castlecary Limestone, the top of the Carboniferous Limestone group, shows a remarkable variation from north to south along the line of outcrop. At Castlecary and Cumbernauld House it is a light grey crystalline encrinital limestone, 4 to 7 ft. thick. In the Glencryan Mine, a mile south of the last named locality, it has become a dark, compact, very ferruginous rock less than a foot in thickness. A similar character is retained in the few exposures seen between Glencryan and Glenboig, but in two bores lately put down to the south of Glenboig, what appears to be the Castlecary position is occupied by a purer limestone 2 ft. in thickness.

## MILLSTONE GRIT.

Hinxman. A closer examination of the field evidence than was perhaps possible at the time of the original survey of the area, together with the large amount of new information afforded by the opening up of the fireclay fields in the Cumbernauld district, has resulted in a considerable alteration of the existing map in the region between Cumbernauld and Glenboig. The area is traversed by a series of powerful faults, having a general east and west trend and a common downthrow to the south, by each of which the outcrops of the Millstone Grit and Coal-measures are stepped successively further to the east. Between Cumbernauld and Castlecary, a fault with a contrary downthrow to the north, estimated at 60 fms. in amount, truncates a basin of the Millstone Grit and shifts the natural outcrop of the formation for nearly two miles to the west.

*Cumbernauld District.*—The lower portion of the Millstone Grit, the home of most of the valuable fireclays which form the principal industry in this district, is well seen at many

localities along the line of outcrop. The Glencryan fireclay mine has been driven ¾ mile north-eastwards to the dip, and affords an admirable section. Starting on the outcrop of the Lower Fireclay, which lies about 15 ft. above the "cement" limestone seen in the tramway cutting 250 yds. from the mine mouth, it passes through a fault throwing down to the south. On the upthrow side of this fault the section commences a short way below the Castlecary limestone, and the sequence, in descending order, is as follows:—

| | Ft. | in. |
|---|---|---|
| Hard yellow sandstone (roof of mine)... | 0 | 0 |
| Lower fireclay (mined) ... ... ... | 4 | 9 (av.) |
| Sandstone ... ... ... ... ... | 9 | 0 |
| Inferior fireclay ... ... ... | 4 to 6 | 0 |
| "Cement" limestone in two bands with shale parting ... ... ... ... | 1 | 6 |
| Dark shale... ... ... ... ... | 0 | 2 |
| Coal... ... ... ... ... ... | 0 | 2 |
| Faky fireclay ... ... ... ... | 3 | 0 |
| Sandstone ... ... ... ... ... | 35 | 0 |
| Dark shales with clayband ironstone nodules ... ... ... ... ... | 5 | 6 |
| Rough ferruginous limestone (Castlecary) ... ... ... ... ... | 0 | 7 |
| Shales ... ... ... ... ... | 0 | 2 |
| Soft sandstone with hard ribs and fireclay bands ... ... ... ... | ? | |

A sequence comparing very closely with that found at Greenfoot (Glenboig).

The "Cementstone," which lies 30—45 ft. above the Castlecary Limestone and 12—20 ft. below what is, in this district, the most valuable seam of fireclay, has been more or less continuously traced in bores and natural sections from Kilt, east of Cumbernauld, to Mossywood, 2 miles N.E. of Glenboig. In most places it is a fairly pure, shelly limestone rather than a cementstone, and is characterised by abundant *Orthotetes crenistria*. A particularly good section showing the limestone, the underlying coal and the associated seams of fireclay, is seen on the Luggie Water near Wester Glentore. A series of bores put down by the Glenboig Union Fireclay Co. in the ground between Blairlinn and the east and west dolerite dyke, have proved that this area is occupied by Millstone Grit strata, and that the course of the fault westwards from Glenhove is considerably to the north of that indicated on the existing map.

Mr. Wilson.

A part of the ground not yet examined intervenes between the Cumbernauld area and the belt of Millstone Grit on the west side of the Falkirk basin revised by Mr. Wilson. Within this belt, and at a position approximately 150 ft. below the Slaty Band Ironstone at the base of the Coal-measures, are situated the fireclay and ganister beds of Bonnybridge. Associated with these fireclays, and resting immediately above them, is a 16 in. coal whose outcrop has been traced from Greenhill Junction to the Bonnybridge reservoir. This coal is used in the fireclay works for furnace purposes.

The section shown in the workings at Bonnybridge is as follows:—

| | Ft. | in. | |
|---|---|---|---|
| Coal ... ... ... ... | 1 | 4 | Upper working. |
| Rib ... ... ... ... | 0 | 3 | |
| Ganister ... ... ... | 2 | 10 | |
| Fireclay ... ... ... | 5 | 0 | |
| ,, ... ... ... | 2 | 0 | Lower working. |
| Ganister ... ... ... | 1 | 6 | |
| Fireclay ... ... ... | 1 | 8 | |
| Ganister ... ... ... | 1 | 0 | |

To the south of Bonnybridge, Millstone Grit strata are seen in several natural sections, and a bore put down by Messrs. Addie and Miller at South Drum gives the thickness of the series from the Slaty-Band Ironstone to the Castlecary Limestone at this point as 115 fms. A comparison of this bore with others further to the south shows a rapid increase northwards in the thickness of the Millstone Grit, the figure quoted from the South Drum boring, 690 ft., being more than double that obtained in bores recently put down to the south of Glenboig.

The South Drum section shows that the lower fireclays associated with the cement limestone are also present in this part of the area.

## COAL-MEASURES.

r. Crampton. The underground mining information relating to two of the most important coalfields in the Falkirk area not being at present available, the correlation and description of the coal seams in this area is deferred to a future Report.

The surface geology of the ground to the north of Falkirk has been revised, and mining information obtained from some of the collieries. Owing, however, to the want of information referred to above, the complete revision of the area has been interrupted and the description consequently deferred to a later date.

[r. Wilson. *Falkirk Area.*—The Falkirk basin may be defined as the area lying between Bonnybridge, Polmont and the Gardrum Moss. The structure of this part of Stirlingshire is a shallow syncline, in which the deepest pit, sunk to a seam nearly at the base of the series, is only 62 fms. The basin is further traversed by several east and west faults. Of these, that one which runs from Glenrig School to Vellore is known locally as the "Universal Dyke," while the next to the south, that crosses Gardrum Moss, is named the Summerhouse fault. Both these have a downthrow to the south. Another important fault with a contrary downthrow to north crosses the area westwards from Glen Village to Bonnybridge, and is probably continued in the dislocation which bounds the Banknock coalfield on the south.

The central part of the basin is occupied by the lower members of the Coal-measures. The outcrop of the Slaty Band Ironstone at the base is well defined along the west side of the syncline, and, together with the associated strata including the Ballstone Ironstone and Craw Coal, is exposed on the Caledonian Railway cutting near Bonnyside and in the burn south of Rough Castle.

This ironstone was largely worked in the past by shallow mines driven from the crop, but on account of its lenticular habit was always a hazardous subject for exploitation. The competition of cheap foreign ores has now completely killed the ironstone mining industry in the Falkirk district.

Coal is now being raised in this district by the following companies:—The Callendar Coal Co.; Forrester & Co.; the Jawcraig Coal Co.; Nimmo & Co.; the Strathavon Coal Co.; and the Carron Coal Co.

New mining information has been obtained from all these collieries with the exception of those belonging to the last named Company; but the data being thus incomplete, the tabulation of the coal-bearing strata, and the exact correlation of the seams with those in adjoining coalfields must await the completion of the revision of this district.

The principal seams wrought in the area are, the "Splint" coal of the Falkirk district, probably the equivalent of the Upper Drumgray; the Coxroad or "Soft" Coal, corresponding to the Lower Drumgray; the Ball Coal, approximately 25 fms. below the "Soft"; and the "Main" of Messrs. Nimmo's Redding field, 5 fms. below the Ball Coal.

The Ball Coal derives its name from the clayband ironstone nodules contained in the shale roof of the seam. These vary from 1 lb. to 6 cwts. in weight and are veined with white calcite. They are taken out in the "brushing" of the seam and smelted by the Shotts Iron Company. The "splint" and "soft" coals in the High Stanerig field are both slightly burnt by the large east and west dolerite dyke which intersects the area.

Mr. Carruthers.

*Greengairs.*—In the area revised in the Greengairs district, all the coal-seams worked at the present time lie comparatively close to the surface, and as they have been extensively wrought since the previous survey, considerable additions and some little alteration have been made in the published map.

The sequence lies in the lower half of the Coal-measures, ranging from the Slaty Band Ironstone up to the Splint and Humph coals. The upper part of this series, down to the Upper Drumgray coal inclusive, is by far the most productive; these upper seams are now, however, approaching exhaustion, and more particular attention has consequently been given to the mapping of the underlying seams, between the Upper Drumgray and the Slaty Band Ironstone, since these must largely be relied upon for any future development of the field.

GENERAL SECTION OF THE LOWER COAL-MEASURES IN THE GREENGAIRS DISTRICT.

| | Fms. | ft. | in. |
|---|---|---|---|
| (15) Splint coal— | | | |
| Strata ... ... ... | 9 | 0 | 0 |
| (14) Musselband coal— | | | |
| Strata ... ... ... | 5 | 0 | 0 |
| (13) Airdrie blackband ironstone— | | | |
| Strata ... ... ... | 11 | 0 | 0 |
| (12) Virtuewell or Johnstone coal— | | | |
| Strata ... ... ... | 7 | 0 | 0 |
| (11) Lady Grange coal— | | | |
| Strata ... ... ... | 6 | 0 | 0 |
| (10) Kiltongue Musselband (ironstone or shale)— | | | |
| Strata ... ... ... | 7 | 0 | 0 |
| (9) Kiltongue coal— | | | |
| Strata ... ... ... | 3 | 0 | 0 |
| (8) Lime or Drumbowie coal— | | | |
| Strata ... ... ... | 2 | 3 | 0 |
| (7) Upper Drumgray coal— | | | |
| Strata (with a thick post of sandstone) ... ... | 14 | 0 | 0 |
| (6) Lower Drumgray or Coxroad coal— | | | |
| Strata (chiefly sandstone)... | 10 | 0 | 0 |
| (5) Coal— | | | |
| Strata ... ... ... | 5 | 0 | 0 |
| (4) Coal— | | | |
| Strata (with a thick post of sandstone) ... ... | 10 | 0 | 0 |
| Musselband ironstone in beds. | | | |
| (3) Coal ... ... ... ... | 0 | 0 | 2 |
| Fireclay ... ... ... ... | 0 | 2-15 | 0 |
| Strata ... ... ... | 5 | 0 | 0 |
| Blaes and balls ... ... ... | 1 | 4 | 0 |
| (2) Coal ... ... ... ... | 0 | 0 | 6 |
| Strata (sandstone)... ... | 8 | 0 | 0 |
| (1) Coal and slaty band ironstone. | | | |

The upper seams down to the Upper Drumgray call for no special remark and may be briefly dismissed.

No. 12 seam, the Johnstone or Virtuewell, has associated with it an oil shale which was worked many years ago at Wattston, ½ a mile S.W. of Greengairs. The shale, though of good quality, proved too thin to compete successfully with the thick shales now wrought in the Lothians. An oil shale is also often found with the Kiltongue Musselband (10); but in this particular district it is usually replaced by an impure clay ironstone, up to 18 ins. in thickness. In the past this has been wrought to a small extent at Blacktongue and at the S.W. side of Greengairs, while the outcrop may be seen in the stream bank south of Rig.

No. 9, the Kiltongue seam, is an excellent house coal, [illegible]orkable round Greengairs, but rapidly thinning away to the [illegible]ast. No. 8, the Lime or Drumbowie coal is very local in its [illegible]ccurrence and somewhat erratic in thickness; between it and

the Upper Drumgray coal (7) is found throughout the district a "musselband" almost wholly composed of the remains of *Carbonicola robusta*, forming a good index to the position. The Upper Drumgray (7) is the leading seam of the district, and is an excellent coal for locomotive and general steam raising purposes.

No. 6 coal, the Coxroad or Lower Drumgray, is poorly developed round Drumgray itself, but improves to the north and east of Greengairs, where it has been worked to a considerable extent near Easter Glentore; the seam is there 18 to 24 ins. thick and of fair quality. No. 5 coal is seen in the east bank of the small stream between Loanhead and Shiels. It is there 14 ins. thick but very foul; further west, however, it improves considerably in quality, though only 12 ins. thick where seen in a trial opening, driven in from the roadside, at the west end of Blacktongue Plantation. The position is a constant one, and the coal would probably be found to thicken when followed further in from the crop; the evidence from bores, however, does not give a greater thickness than 20 ins.

No. 4 seam, locally known as the "Smithy" coal, and probably the equivalent of the "Ball" coal of the Falkirk coalfields, is the thickest of this lower series, but is of poor quality and has a soft roof. To the south and west of Greengairs it appears to deteriorate both in thickness and quality. This coal has been worked to some extent at the West Glentore Colliery between Langdales and Loanhead, and attempts were also made many years ago to mine it from the outcrop under the west side of the road a few hundred yards N.W. of Shields, and in shallow pits by the stream close by.

This, and the three remaining seams, all reach their fullest development in the neighbourhood of Auldshields, where they contain thin ribs of Black Band Ironstone (rarely more than one or two inches in thickness) a feature apparently absent in other parts of the district.

In the case of No. 4 coal, the ironstone is found a few inches below the base of the coal; and over twenty years ago an attempt was made to work the two in conjunction from a trial shaft sunk close to the old ironstone pit east of Auldshields Bridge.

No. 3 is a thin bedded impure ironstone (possibly equivalent to the Bowhousebog ironstone), full of "mussels" (*Carbonicola* and other lamellibranchs, with fish remains) cropping out along the top of the east bank of Auldshields Glen, where it averages six inches in thickness. Eastwards towards Langdales the thickness increases, but the seam apparently remains of poor quality, as no attempts seem to have been made to work it. Together with the thick underlying fireclay it forms a very constant position in the district.

No. 2, though locally containing a black-band ironstone rib, appears to have no economic value. No. 1 is the slaty (Black-band) ironstone and coal, worked many years ago at Auldshields, both from a pit east of the bridge, and from th

outcrop along the bottom of the gorge, where it may be seen under the sandstone cliff.

It has been observed* that the lowest Slaty Band Ironstone of other districts is characterised by a typical marine fauna (*Productus* &c.), but the Auldshields Slaty Band, though the lowest of which we have any knowledge in this district, does not appear to contain such fossils, and indeed is remarkably barren of organic remains.

Some compensation for the general inferiority both in quality and thickness of these seams below the Upper Drumgray coal, may be found in the fact that the beds almost always lie at a very gentle angle, so that in many cases shallow sinkings only would be required to win a fairly large area of coal. A thin whin "float," not more than four feet in thickness, occurs between beds (2) and (3) in the ground to the north and west of Greengairs. It is possible that this may represent the large "float" lying below the Upper Drumgray coal to the east (in the Slamannan district) of which there is otherwise no trace near Greengairs.

nderson. *Slamannan District.*—In the southern part of Slamannan parish the highest seam present is the Johnstone or Virtuewell. This seam and the underlying Ladygrange, Splint or Upper Drumgray, and Coxroad or lower Drumgray, have been almost entirely wrought out, while the Kiltongue Coal does not occur as a seam of workable thickness. A thin oil-shale on the top of the Virtuewell Coal was taken out along with the coal, and oil-works were erected for its treatment. An attempt was also made to work the Musselband shale which occurs between the Ladygrange Coal and the position of the Kiltongue. Noticeable "wants" occurred in the Virtuewell and Splint seams. In both cases these were elongated so as to suggest stream erosion, that in the Virtuewell running south-east, and that in the Splint a little south of east. In neither case was there any trace of the want in the seams above or below.

In the district north of the Avon, the Coxroad Coal is being worked at Bankrigg Colliery not far west of Avonbridge, and the Coxroad and Splint Coals from some of the Redding pits a little to the north. In the Splint or Upper Drumgray Coal workings from Redding No. 24 pit, a remarkable "want" occurs. A bed of soft laminated sand replaces the coal, with the roof of the latter persisting over the sand for part of its breadth. In some places fragments of coal are attached to this roof and project downwards into the sand bed, showing clearly that the coal has been replaced subsequently to the consolidation of the roof of the seam, and probably at some quite recent period. There is no visible connection with the surface, but probably the sand is due to the action of underground water, which has eroded the coal and then filled up its own channel.

* W. Grossart. *Trans. Geol. Soc., Glasgow*, vol. iii., p. 99, 1870.

### PLEISTOCENE AND RECENT.

A narrow belt of well-defined east and west ridges of sand and gravel runs westwards from Laurieston to Bonnybridge, clinging closely to the 100 ft. contour line. Advantage was taken of this natural feature in constructing the Roman Wall of Antoninus Pius (A.D. 140),—the earthen rampart so conspicuous in the neighbourhood of Camelon. From Bonnybridge the gravels extend for some distance up the Bonny Water and Carron River, and then, turning eastwards by Larbert, pass northwards to Plean and Stirling. In this part of the area they have a distinctly terraced arrangement, and rise to an elevation of about 125 ft. These sands and gravels appear to have been laid down along the landward margin of a mass of ice which occupied the estuary of the Forth towards the close of the Glacial Period. Mr. Wilson and Dr. Crampton.

### ECONOMICS.

*Coal.*—The coals raised in the Falkirk district are chiefly of the household type, while the Ball coal is a second class steam coal. The "soft" coal at the Jawcraig Colliery, besides being a first class household coal with a heavy brown ash, possesses excellent coking qualities. The same seam is coked by the Redding Coal Co., near Blackrig. The ovens are of the usual bee-hive type. Mr. Wilson.

The Kiltongue seam in the Greengairs district, and the Lower Drumgray or Coxroad in the area to the north-east of Slamannan, are good household coals, while the Upper Drumgray of Greengairs is raised for general steam purposes. Mr. Anderson and Mr Carruthers.

*Fireclay.*—A valuable seam of fireclay is mined at Glencryan, 1½ miles south-south-east of Cumbernauld, by the Glenboig Union Fireclay Co. The seam lies about 40 ft. above the base of the Millstone Grit, on the same geological horizon as the fireclay worked by the same Company at Gain and Glenboig. The clay is of excellent quality, and is used for the manufacture of bricks and blocks for furnaces, drain pipes, ornamental tiles, and other fireclay goods. Mr. Hinxman

Fireclays, considerably higher up in the series, are worked by several companies at Bonnybridge, at an approximate position 120 to 150 ft. below the slaty band ironstone. The Bonnybridge seam has an average thickness of 12 ft., and consists of alternating bands of ganister and fireclay, the whole varying much both in thickness and quality. Analyses made for Messrs. Dougal of the Bonnyside works by Messrs. Tatlock and Thomson, Glasgow, show a percentage of 95% of silica for the ganister, and 55% for the fireclay. The latter is made into ordinary fireclay bricks, while the ganister supplies a higher class of fire-resisting goods. Mr. Wilson

The fireclay at the base of the Coal Measures wrought at Rough Castle, 1½ miles east of Bonnybridge, by Messrs. Campbell & Co., contains 64% of silica and is used for ordinary

fireclay goods. The fireclays of Bonnybridge and Rough Castle all contain plant remains, and the presence of iron pyrites in the clays gives rise to a speckled appearance in the articles manufactured from them. At the Glen Works, Callendar, a seam of fireclay immediately below the Coxroad Coal is mined for the production of high-class sanitary goods.

There is a ready market, both home and foreign, for the finished products of all the above-mentioned fireclay works; and at Rough Castle there is also a considerable export trade in the raw material, the ground fireclay going to South America to be used for furnace linings.

. Wilson. *Oil Shale.*—An oil shale of good quality is associated with the Miller's Coal, a seam about 30 fathoms above the Coxroad, at Wester Pirleyhill and in the Polmont burn at Redding. It is separated from the underlying coal by a musselband ironstone, and overlaid by a thick bed of speckled grey sandstone.

A sample from the Pirleyhill burn, where the seam is twenty-two inches thick, has been analysed by Mr. Stewart, Chemist to the Broxburn Oil Co., and gives the following result:—

Oil—25·47 gallons per ton.
Spec. gravity, ·903.
Setting point, 96° Fah.
Sulphate of ammonia, 12·54 lbs. per ton.

As all chemists who deal with oil shale are aware, the amount of sulphate of ammonia obtained by laboratory analysis is only half that got when a large quantity of shale is retorted. This seam should therefore prove a valuable one.

. Wilson. *Moss Litter.*—A new industry has recently been established in the Falkirk district, where the Griendtsveen Moss Litter Co., Ltd., have leased the Gardrum and neighbouring peat mosses. The employees are all Dutch, who, under favourable weather conditions can earn as much as £3 per week. The material used is the loose brown peat which forms the upper part of the moss. This is dug out, placed in stacks, and air dried, being afterwards compressed by mechanical means into bales suitable for transport. The Company further propose to erect plant for grinding the peat into packing for fruit and vegetables.

. The peat in the Cardowan Moss, ½ mile south-east of Steps Hinxman. Road Station, Lanarkshire, is also being dug for moss litter and packing purposes.

. Wilson. *Water Supply.*—The water supply of the south-eastern portion of Stirlingshire has, until recently, been very deficient, and largely derived from shallow surface wells. It is now, however, being gradually improved by the County Council, who are introducing a gravitation supply from the catchment area around Loch Coulter in the north-west.

*Agriculture.*—A notable change in the agricultural conditions of that part of Stirlingshire which lies south of Falkirk and Bonnybridge has taken place within the last 60 years, the

ground that at one time was under the plough being now almost completely in pasture and devoted to dairying. This change from arable to pasture dates from the development of the industries associated with the mineral belt of Central Scotland, the consequent great increase in the population creating a large and permanent demand for dairy produce.

## II.—PALÆONTOLOGICAL WORK.

The Palæontological Department in Scotland was carried on under the general supervision of Dr. Kitchin, by Messrs. Crampton and Carruthers during the first part of the year, and latterly by Dr. Lee, with the assistance of Messrs. Macconochie, Tait, and McVey. Dr. Lee.

The total number of specimens gathered during the year and entered in the Survey list books amounts to 1,795, all of which belong to the Carboniferous formation. The fishes have been determined by Dr. Traquair, the plants by Dr. Kidston, the lamellibranchs by Dr. Wheelton Hind, and the other groups by Dr. Crampton and Dr. Lee.

Since Dr. Lee's appointment in May the efforts of the Palæontological staff were mainly directed to the arrangement, in permanent order, of the extensive collection of fossils, in accordance with the recommendations of Dr. Kitchin. The fossils gathered by the late Mr. Bennie, amounting to upwards of 40,000 specimens, are now, with the exception of those exhibited in the Royal Scottish Museum, arranged according to their registration numbers in new cabinets that have been provided for that purpose. To facilitate references a card catalogue of the fossils, on a strictly topographical basis, is now in course of preparation.

During the year an important discovery of Carboniferous plants has been made in the group of red sandstones forming the highest portion of the Coal-measures in Ayrshire, which has enabled Dr. Kidston to correlate the plant-bearing strata there with their stratigraphical equivalents in England.

Last summer Mr. J. Smith, of Dalry, gave information that a new pit—the Barony pit—was being sunk by Messrs. Wm. Baird & Co., Ltd., through these red barren sandstones and clays nearly a mile and a half west of Auchinleck, Ayrshire. Mr. Smith had already visited the site and, from the material brought up from the sinking, had collected specimens of fossil plants, which Dr. Kidston has determined to belong to the horizon of the Upper Coal-measures. As far as known these are the first specimens from Scotland which have been assigned to this horizon, for the specimens previously collected by Mr. Macconochie, from Jockie's Sike, Liddisdale,* were all found

* "The fossil plants of the Carboniferous Rocks of Canonbie, Dumfriesshire, and parts of Cumberland and Northumberland." *Trans. Roy. Soc. Edin.*, vol. xl., p. 741, 1903. See also "The Canonbie Coalfield: its Geological Structure and Relations to the Carboniferous Rocks of the North of England and Central Scotland," by Dr. Peach and Dr. Horne, *Trans. Roy. Soc. Edin.*, vol. xl., p. 835.

on the English side of the border, though no doubt the bed containing them extends into Scotland.

After Mr. Smith's visit Mr. Tait collected a large suite of fossil plants from fragments chiefly of reddish purple clayey shale brought up from the sinking. The collection was submitted for determination to Dr. Kidston, who has furnished the following report.

Dr. Kidston.

"LIST OF FOSSIL PLANTS FROM THE 'RED BEDS' ABOUT 50 FATHOMS FROM SURFACE, PASSED THROUGH IN SINKING THE SHAFT OF THE BARONY PIT, AT OLDBYRES FARM, ABOUT 1½ MILES WEST OF AUCHINLECK, AYRSHIRE."

*Sphenopteris* sp. (I.)
,, sp. (II.)
*Pecopteris arborescens* Schloth. sp.
,, *cyathea* Schloth. sp.
,, cf. *unita* Brongn.
,, *miltoni* Artis sp.
,, sp.
*Odontopteris lindleyana* Sternb.
*Neuropteris ovata* Hoffm.
,, *flexuosa* Sternb.
,, *rarinervis* Bunbury
,, *scheuzeri* Hoffm.
,, *impar* Weiss sp.
,, (*Cyclopteris*) *orbicularis* Brongn.
*Spiropteris* sp.
*Calamites undulatus* Sternb.
,, *ramosus* Artis
,, sp.
*Asterophyllites equisetiformis* Schloth. sp.
*Annularia stellata* Schloth. sp.
*Sphenophyllum emarginatum* Brongn.
,, *longifolium* Germar
*Lepidodendron dichotomum* Sternb. (Zeiller).
,, *lanceolatum* Lesq.
,, cf. *fusiforme* Corda sp.
*Lepidostrobus variabilis* L. and H.
*Sigillaria camptotoenia* Wood sp.
,, *discophora* König sp.
*Stigmaria.*
*Pinnularia capillacea* L. and H.

The material from which the list is drawn up was collected by Mr. John Smith, Dalry, and Mr. D. Tait.

The collections contained at least two species of *Sphenopteris* but they were too imperfect for a specific determination. Among the examples of *Pecopteris* were a number of specimens on which the nervation was not shown, and hence could not be determined with any certainty, but probably other species of the genus occurred than those included in the list. *Neuropteris impar* Weiss sp. I have not previously seen from so high a horizon.

A comparison of the species contained in this list is, however, sufficient to show that the rocks from which the plants were collected belong without doubt to the Radstockian series,*

* Kidston, *Quart. Jour. Geol. Soc.*, vol. lxi., pp. 319—320, 1905.

though probably to its lower portion. These "Red Beds" at Barony Pit I regard as on the same horizon as the Keele group of North Staffordshire, and the beds at Jockie's Sike, Cumberland."*

From information kindly provided by Messrs. Wm. Baird & Co. it appears probable that the clay shale from which the named specimens were collected occupies an horizon, which, in a diamond bore near the sinking, lies about 196 fathoms above the highest coal found in the bore, and 230 fathoms above the Ell coal, the highest workable seam. For about 177 fathoms below the supposed position of the plant bed nearly all the beds, whether of blaes, fakes or sandstone, are red in colour, or red mottled with blue, green and buff. But just below these strata the bore journal records a bluish limestone six-inches thick, underlaid, for a distance of 16 fathoms, by beds which are for the most part red, but mixed with some grey and blue beds. Further down the red colour disappears. No cores of this limestone have been examined by the Survey, but it seems not unlikely that it may be a marine limestone, and in much the same stratigraphical position as those which occur near the base of the Upper Carboniferous red barren measures in other parts of Scotland.† Dr. Lee.

Mr. Tait also found blocks of *Spirorbis* limestone which had been brought up from the Barony Pit-shaft from a position, according to the leading sinker, about 30 fathoms above the plant bed. This limestone has a close resemblance lithologically to the *Spirorbis* limestone of Ballochmyle, which was found near the top of the Upper Carboniferous red barren measures of Ayrshire by Mr. E. W. Binney many years ago.‡ It has also been observed at Barwharrie, 1½ miles south of Ochiltree, so that it forms an important horizon in these red beds in Ayrshire.

Mr. E. W. Binney also noted the occurrence of a band of *Spirorbis* limestone in the Upper Carboniferous red measures of Canonbie, Dumfries-shire,§ but it is uncertain whether it overlies or underlies the plant bearing bed at Jockie's Sike.

A band of limestone with a close lithological resemblance to that recorded by Mr. Binney, near Canonbie, occurs some distance above the plant bed of Jockie's Sike, but no specimens of *Spirorbis* were noticed.

Dr. Crampton has kindly furnished the following information on some deep bores in Fifeshire. Dr. Crampt

"Three bores on the lands of Messrs. Balfour of Balbirnie and Newton Don, in Fifeshire, were examined in the early

* Kidston. *Trans. Roy. Soc., Edin.*, vol. xl., part iv., p. 802, 1903. A specimen of *Palæoxyris carbonaria* Schimper was found by Mr. Tait.

† These marine limestones are described in the Appendix of this year's Summary of Progress, p. 127, by Messrs. Smith and Clough.

‡ "On some Upper Coal Measures containing a bed of limestone at Catrine Ayrshire." *Quart. Jour. Geol. Soc.*, vol. xviii., p. 437, 1862.

§ "Further examinations on the Carboniferous, Permian, and Triassic strata of Cumberland and Dumfriesshire." *Mem. Manchester Lit. and Phil. Soc.*, vol. ii., p. 343.

part of the year by Messrs. Grant Wilson, Crampton, and Tait, at the instance of the estate management. The factor, Mr. Balingall, aided them in their examination. A number of fossil plants, lamellibranchs, brachiopods, corals, etc., were obtained from the cores, and have been determined by Dr. Kidston, Dr. Wheelton Hind, Messrs. Crampton and Carruthers. By means of the plant remains determined by Dr. Kidston it was shown that Balgonie No. 8 Bore and Trenton Bore passed through between 700 and 800 ft. of the Wemyss Coal-measures with several good workable seams. The latter bore then passed through a fault in the Upper Limestones and Limestone Coals. A considerable area of good workable coals of the Upper Wemyss Coal-measures has thus been proved over an area previously considered to be occupied by the Carboniferous Limestone Series."

. Lec. Messrs. Tait and McVey collected the fossils from the cores of a deep bore put down near Markinch, Fife, by Messrs. Thomson, of Dunfermline. An interesting suite of fossils was obtained from the strata between the Millstone Grit and the Lower Hosie Limestone. Fragments of what appears to be *Orthotetes crenistria* (Phill.) are more numerous at the horizon of the Roman Cement, whilst *Schizophoria resupinata* (Mart.) and various Productids, including *Productus latissimus* J. Sow., are plentiful when approaching the horizon of the Calmy Limestone. Many isolated specimens belonging to various forms were met with throughout the section. Among the plants some well-preserved specimens of *Stigmaria stellata* Goepp. were obtained from a shale overlying the Index Limestone.

r. arruthers. "Considerable progress can be reported in the revision of Carboniferous corals now proceeding. To obtain results of permanent value, it has been found necessary to examine material procured from the original sources of various species. During the past year permission was kindly given by the authorities of the British Museum (Natural History) to examine a suite of Belgian specimens there deposited, these being first taken to Brussels for comparison with types preserved in the Musée d'Histoire Naturelle, and afterwards so treated that a revision of the original diagnoses could be prepared. The results so obtained were supplemented by the examination of material in the Survey and various private collections. Our cordial thanks are due to the owners of these collections for the loan of their material, especially to Dr. A. Vaughan, whose assistance has been invaluable. An account of these investigations is, at the present time (January 1908) appearing in the "Geological Magazine," as they are not sufficiently advanced to be embodied in a Survey Memoir.

Early in the summer the Cementstone Series and Lower Limestones of Liddisdale were carefully collected by Mr. Macconochie. A peculiar interest attaches to the forms thus obtained, since this is almost the only district in Scotland in which a fauna approaching in facies that of a normal marine type, occurs in the basal members of the Carboniferous system.

Amongst other corals, a large number of typical examples of *Zaphrentis delanouei* M. Edw. and Haime were found in the upper part of the Cementstone Series. From the material so far obtained, the species appears to undergo a gradual evolution in passing upwards into the Lower and Upper Limestone Groups. Further investigation of this point is proceeding, as a separation of these horizons is important from an economic as well as a palæontological point of view."

Dr. Lee.

The following is a list of Geological Survey specimens which have been figured and described during the year;—

### In the Palæontographical Society's Volume for the Year 1907.

#### By Dr. R. H. Traquair, F.R.S.

*Carboniferous Ganoid Fishes.*

Elonichthys striatulus *Traq.*, pl. xx., figs. 3, 4, 5.

#### By Miss Elles, D.Sc., and Miss Wood, D.Sc.

*British Graptolites.*

Diplograptus (Orthograptus) bellulus *Törn.*, pl. xxix., figs. $2_a$, $2_d$.
,, calcaratus, *var.* tenuicornis *var. nov.*, pl. xxx., fig. 4.
,, ,, *var.* acutus *Lapw.*, pl. xxx., fig. $3^c$.
,, (Amplexograptus) perexcavatus *Lapw.*, pl. xxxi., fig. $15^c$.
,, (Orthograptus) rugosus, *var.* apiculatus *var. nov.*, pl. xxx., fig. $7^a$.
,, truncatus *Lapw.*, pl. xxix., fig. $3_c$.
,, vesiculosus *Nich.*, pl. xxviii., fig. 8d.
,, ,, *var.* penna *Hopk.*, pl. xxviii., fig. $9^c$.
,, whitfieldi (*Hall*), pl. xxviii., figs. $6^a$, $6^b$.
,, (Glyptograptus) tamariscus *Nich.*, pl. xxx., fig. $8_a$.
,, ,, teretiusculus, *var.* euglyphus *Lapw.*, pl. xxxi., fig. $2^b$.

#### By Miss Ida Slater, B.A.

*British Conulariæ.*

Conularia hastata *sp. nov.*, pl. iv., fig. 1.
,, tenuis *sp. nov.*, pl. ii., fig. 1.

### In the Transactions of the Royal Society of Edinburgh, Vol. XLVI, 1907.

#### By Dr. R. H. Traquair, F.R.S.

*Fossil Fishes from Gullane.*

Elonichthys robisoni (*Hibb*), pl. i., fig. 1.
,, striatulus *Traq.*, pl. i., figs. 2, 3, 4.
Gonatodus punctatus (*Ag.*), pl. ii., figs. 1, 2.
Rhadinichthys brevis *Traq.*, pl. ii., figs. 3, 4, 5.
,, formosus *Traq.*, pl. ii., figs. 6, 7, 8.
Wardichthys cyclosoma *Traq.*, pl. ii., fig. 9.

# III.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

## A. ENGLAND AND WALES.

### I.—Maps.

#### (*a*) *Four Miles to One-inch.*

New Series. Solid Edition.

Sheet 1 and 2 (Alnwick, Berwick, etc.), price 2s. 6d.
Sheet 3 (Carlisle, Keswick, and part of Isle of Man), price 2s. 6d.
Sheet 4 (Newcastle-upon-Tyne, Stockton, etc.), price 2s. 6d.
Sheet 5 and 6 (Lancaster, Preston, Wigan, Southport, Isle of Man), price 2s. 6d.
Sheet 7 (Leeds, Manchester, York, etc.), price 2s. 6d.
Sheet 23 (Bournemouth, Isle of Wight, Selsey Bill, etc.) price 2s.

New Series. Drift Edition.

Sheet 16 (Cambridge, Colchester, Ipswich, etc.), price 2s. 6d.
Sheet 20 and 24 (London, Dover and Brighton), price 2s. 6d.

#### (*b*) *One-inch Maps* (*New Series*).

Sheet 230, Ammanford (Solid and Drift).
Sheet 247, Swansea (Solid and Drift).
Sheet 254, Henley-on-Thames (Drift).
Sheet 348, Plymouth (Drift).
Sheet 351 and 358, Penzance (Drift).
Sheet 353, Mevagissey (Drift).

#### (*c*) *Six-inch Maps.*

The undermentioned six-inch maps have been published with geological information (uncoloured):

Brecknockshire.—48 N.W., 49 N.E., 50 N.W., N.E.
Glamorganshire.—10 N.W., S.W., S.E., 11 S.W., S.E., 17 N.W., N.E., S.W., S.E., 18 N.W., N.E., S.W., S.E., 27 N.W., N.E., S.W., 35 N.W., S.W., S.E., 41 N.W., N.E.
Monmouthshire.—12 S.W.
Staffordshire.—13 N.W., 19 N.W. (Drift only), N.E. (Solid only), S.W.

#### (*d*) *MS. Six-inch Reference Maps.*

Seventy MS. coloured copies of six-inch quarter sheets have been made from the field-copies, and deposited in the Office for Public Reference. They are as follows:—

Cornwall.—(24 S.W. and 24 S.E.), 24 S.E., 25 S.W., 26 S.E., 27 N.W., S.W., 32 S.E., 33 N.W., N.E., S.W., S.E., 34 N.W., S.W., 40 N.E., S.E., 41 N.W., N.E., S.W., S.E., 42 N.W.

Essex.—65 N.W., 73 S.E.
Gloucestershire.—2 S.E.
Leicestershire.—11 S.E., 12 N.E., S.W., S.E.
London.—4 N.W.
Merioneth.—19 N.E., S.W., S.E., 26 N.W., S.W., S.E., (31 S.E. and 32 S.W.), 32 N.E., 36 N.W. (portions with mining information).
Middlesex.—2 S.E., 7 S.W., 9 N.E., S.E.
Northumberland.—3 N.E., S.W., S.E., 4 S.W., 7 N.W., N.E., S.W., S.E.
Nottinghamshire.—33 N.E., 42 S.W., S.E., 46 N.W., N.E., S.W., S.E., 47 N.W., N.E., S.W., S.E., 50 N.W., N.E., S.W., 51 N.W.
Surrey.—1 S.E., 11 N.E., 12 N.E.
Warwickshire.—6 N.W., S.W., 44 N.E.

## II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1906, pp. 181. Price 1s.

The Geology of the South Wales Coalfield.—Part VII., The Country around Ammanford (Sheet 230), by Aubrey Strahan, M.A., Sc.D., F.R.S., T. C. Cantrill, B.Sc., F.G.S., E. E. L. Dixon, B.Sc., F.G.S., and H. H. Thomas, M.A., B.Sc., F.G.S., pp. 246. Price 2s. 6d.—Part VIII., The Country around Swansea (Sheet 247), by Aubrey Strahan, with parts by R. H. Tiddeman, M.A., F.G.S., W. Gibson, D.Sc., F.G.S., and E. E. L. Dixon, and a Supplementary Geological Bibliography of South Wales and Monmouthshire, by O. T. Jones, M.A., B.Sc., pp. 170. Price 2s. 6d.—Part IX. West Gower and the Country around Pembrey (Sheet 246), by A. Strahan (in part from Notes by B. S. N. Wilkinson, T. C. Cantrill, and E. E. L. Dixon), pp. 50. Price 8d.

The Geology of the Country around Hungerford and Newbury (Sheet 267), by H. J. Osborne White, F.G.S., pp. 150. Price 2s. 6d.

The Geology of the Land's End District (Sheets 351-358), by Clement Reid, F.R.S., and J. S. Flett, M.A., D.Sc., with contributions by B. S. N. Wilkinson, E. E. L. Dixon, B.Sc., and W. Pollard, M.A., D.Sc.; Mining Appendix by D. A. MacAlister, A.R.S.M., pp. 158. Price 3s. 6d.

The Geology of the Leicestershire and South Derbyshire Coalfield, by C. Fox-Strangways, F.G.S., with Palæontological Notes and List of Fossils by A. R. Horwood, pp. 373. Price 6s.

The Geology of the Country around Plymouth and Liskeard (Sheet 348), by W. A. E. Ussher, F.G.S., with Notes on the Petrology of the Igneous Rocks by J. S. Flett, M.A., D.Sc., pp. 156. Price 3s.

The Geology of the Country around Mevagissey (Sheet 353), by C. Reid, F.R.S., with Notes by J. J. H. Teall, D.Sc., F.R.S., pp. 73. Price 2s.

## B. SCOTLAND.

### I.—MAPS.

#### (*a*) *Four Miles to One-inch.*

Sheet 16 (Kirkcudbright, Ayr, and Mull of Kintyre), price 2s. 6d.

Sheet 17 (Dumfries, and Jedburgh), price 2s. 6d..

#### (*b*) *Six-inch Maps (New Series).*

Edinburgh.—3 N.E., S.E., 4 N.E., 7 N.E., S.E., 8 N.W. S.E., 12 S.E., 13 N.W., N.E., S.W., S.E.
Haddington.—4 S.W., S.E.

### (c) *MS. Six-inch Reference Maps.*

The following MS. copies of six-inch sheets have been made from the field copies and deposited in the Office for Public Reference:—

Argyll.—200.
Caithness.—2, 3, 6, 7, 8, 12, 13, 23, 24, 25.
Elgin.—32, 33.
Inverness.—15, 16, 34, 131.
Ross.—26, 36, 62, 75, 84, 111, 112.

## II.—MEMOIRS.

The Geological Structure of the North-west Highlands of Scotland, by B. N. Peach, LL.D., F.R.S, J. Horne, LL.D., F.R.S., the late W. Gunn, C. T. Clough, M.A., F.G.S., and L. W. Hinxman, B.A., with Petrological Chapters and Notes by J. J. H. Teall, M.A., D.Sc., F.R.S., Edited by Sir Archibald Geikie, K.C.B., D.C.L., Sec. R.S.

The Geology of Islay, including Oronsay and portions of Colonsay and Jura (Explanation of Sheets 19 and 27, with the western part of Sheet 20), by S. B. Wilkinson, with Notes by J. J. H. Teall, D.Sc., F.R.S., and B. N. Peach, LL.D., F.R.S.

## *LIST OF EXTRA OFFICIAL PUBLICATIONS.*


Crampton, C. B.—Fossils and Conditions of Deposit. A theory of Coal Formation. *Edin. Geol. Soc.*, vol. ix., part i., pp. 73-92.

Hinxman, L. W.—The Rivers of Scotland—The Beauly and Conon. *Scottish Geograph. Mag.*, pp. 192-202.

Kitchin, F. L.—Notes on the Invertebrate Fauna of the Uitenhage Series in Cape Colony. *Geol. Mag.*, pp. 289-295.

Lamplugh, G. W.—On the Geology of the Zambesi Basin around the Batoka Gorge. *Quart. Journ. Geol. Soc.*, vol. lxiii., pp. 162-214.

Reid, C.—Evidence on Coast Erosion, with especial reference to Holderness, Norfolk, parts of Sussex, Hampshire, the Isle of Wight, and Cornwall. *Report Roy. Comm. on Coast Erosion*, vol. i., pp. 99-113.

Appendix No. XII. (A) Memorandum on Coast Erosion. *Ibid.*, Appendices, pp. 163-164. (Reprinted from *Geograph. Journ.*, xxviii., pp. 487-495, 1906.)

Appendix No. XII. (B) Memorandum on the Geological conditions affecting the coasts of Holderness, Lincolnshire, and Norfolk, the south coast generally, and the coasts of Cornwall and North Devon. *Ibid.*, Appendices, pp. 165-172.

—— and Eleanor M. Reid.—The Fossil Flora of Tegelen-sur-Meuse, near Venloo, in the Province of Limburg. *Verh. Kon. Akad. Wetensch. Amsterdam.* (Tweede Sectie.) Deel xiii., No. 6.

Smith, B., (W. G. Fearnsides, G. L. Elles, and B. Smith.)—The Lower Palæozoic Rocks of Pomeroy. *Proc. Roy. Irish Acad.*, vol. xxvi., sect. B, No. 9, 1907, pp. 97-128.

Strahan, Dr. A.—Evidence on Coast Erosion, with especial reference to the Isle of Wight, Chesil Bank, and South Wales. *Report Roy. Comm. on Coast Erosion*, vol. i, pp. 129-139.

Thomas, H. H.—Petrographical Notes on Rocks from the Zambesi Basin. *Quart. Journ. Geol. Soc.*, vol. lxiii., pp. 207-211.

——The Geology of the Clarbeston and Letterston Railway. *Gt. Western Railway Mag.*, vol. xix., pp. 197, 223.

Woodward, H. B.—Evidence on Coast Erosion, with especial reference to East Devon and Dorset, and West Somerset. *Report Roy. Comm. on Coast Erosion*, vol. i., pp. 119-125.

—— History of the Geological Society of London. 8vo London.

—— Stanford's Geological Atlas of Great Britain and Ireland. 8vo London.

# APPENDIX.

## 1.—On the Mugearites.

By John S. Flett, M.A., D.Sc.

In the Geological Survey Memoir on the Tertiary Igneous Rocks of Skye Mr. Harker has described the occurrence in the Roineval district of a group of composite sills consisting of olivine dolerite and of a rock which he has called "mugearite."

The latter is a dark, finely crystalline rock, somewhat like a fine dolerite or basalt when fresh, but weathering with a yellow brown colour and a fissile character which give it a resemblance to certain trachytes.* The chief mineralogical peculiarities of mugearite are two. Firstly, the felspar is not labradorite but oligoclase; and, secondly, the ordinary bisilicate minerals are very poorly represented, augite being typically quite subordinate to olivine. The percentage mineral composition of the rock must be approximately as follows:—

| | |
|---|---|
| Oligoclase ... ... ... ... ... | 57½ |
| Orthoclase ... ... ... ... ... | 12½ |
| Olivine, iron ore, and augite... ... ... | 26½ |
| Apatite ... ... ... ... ... ... | 3½ |
| | 100 |

"Felspars of species rich in alkalies thus make up about 70 per cent. of the rock. They appear in thin slices as a crowd of little elongated sections (see Pl. Fig. 1), averaging about .005 inch in length, with parallel or subparallel arrangement at any given point, the microstructure being consequently of the trachytic type. Most of the little crystals show albite twinning, often with repetition. They give nearly straight extinction, and must belong to oligoclase. The untwinned crystals are doubtless to be identified as orthoclase, for the amount of potash in the rock is much too great to be contained in a felspar of the oligoclase type. On this understanding the composition of the oligoclase may be reckoned as nearly $Ab_7An_2$, which agrees with the approximately straight extinction observed.

"Of the other constituents, the olivine forms little well-shaped crystals or rounded grains usually about $^1/_{100}$ inch in diameter. The mineral is commonly fresh. The augite, sensibly colourless in thin slices, has the ophitic habit; but it is present in such small quantity that the several minute pieces belonging to one ophitic plate are only perceived to have that relation by their polarisation. The magnetite is in minute octahedra, and there is often in addition a certain amount of

* "The Tertiary Igneous Rocks of Skye" (*Mem. Geol. Surv.*), 1904, p 265, etc.

limonite of secondary origin. The apatite is in very slender needles."

In the Skye mugearites there is also a brown "problematical mineral," the optical properties of which Mr. Harker describes at some length. I have been able to ascertain that this brown mineral includes both biotite and hornblende, having certain well-marked peculiarities, but the description of these will be deferred for the present.

Since the completion of Mr. Harker's work in Skye and the publication of the memoir above referred to, rocks which correspond very closely in all essential features, chemical, mineralogical and structural, to the Skye mugearites have been found in Midlothian and East Lothian, where they are of Carboniferous not of Tertiary age. Most of them have been mapped as lavas, though it is possible that some may really be thin sills. In no case are they accompanied, as in Skye, by olivine dolerites of the Roineval type, nor do they form composite sills.

The mugearites of the Midlothian district occur in two different localities, in both cases on a horizon not far above the base of the Carboniferous series. On Arthur's Seat they form the uppermost part of the Whinny Hill, and are found also a little to the north of this in the railway cuttings and quarries around St. Margaret's. At Corston Hill, about twelve miles west-south-west of Edinburgh, rocks of the same kind are exposed. At both localities they are accompanied by olivine basalts, which at Arthur's Seat are porphyritic with large crystals of olivine and labradorite (Markle type). These mugearites are dark green, fine-grained, non-porphyritic rocks, weathering red and brown; they have a thin platy jointing, and a parallel arrangement of their lath-shaped felspars which gives their broken surfaces a shimmering lustre. Some of the rocks have a sinuous banding due to fluxion. Their appearance in the field is distinctive and so unlike that of the olivine basalts that their real nature was recognised by Dr. Peach and Mr. E. B. Bailey before they were sliced for microscopic examination.

Under the microscope they prove to be by no means so fresh as the Tertiary mugearites of Skye (Pl. —Fig. 2). They have contained phenocrysts of olivine, in some instances small and numerous, in others larger but less frequent; small porphyritic felspars are also present in some of the rocks. The matrix has an eminently perfect fluxion structure. It consists of long narrow crystals of oligoclase arranged in parallel order. Between these there are decomposition products (calcite, hematite, chlorite, limonite, etc.,) presumably representing original augite. The olivine, also, is entirely decomposed and its former presence can only be inferred from the shape of its pseudomorphs. There are many small octahedra and irregular grains of magnetite. In one of the slides from Corston Hill there are scales of reddish-brown biotite, similar to those in the Skye rocks.

The East Lothian mugearites were recognised as a special type of rock by Mr. Barrow when he mapped the ground, and he noted their resemblance to the mugearites of Eigg. His conclusions were subsequently confirmed by Mr. Harker who made an examination of the rock slices. Mr. Barrow notes that in the field the mugearites are very similar to the trachytes of East Lothian but they are richer in iron oxide and darker in colour. A full account of their field relationships and petrographical characters will appear in the Memoir on East Lothian which is now preparing for the press.

The mugearites of East Lothian correspond to those of Skye in all essential features. They consist principally of olivine and oligoclase with a subordinate amount of orthoclase, augite, hornblende and biotite. The olivine occurs as numerous small phenocrysts. The felspars have lath shapes and are arranged in parallel order (Pl. —Fig. 3). Orthoclase forms peripheral fringes surrounding the oligoclase crystals and can be identified by its lower refractive index. Between the felspars there are patches of decomposition products which may be presumed to represent original augite. Usually the felspars are sufficiently fresh to be determinable but the olivine and augite are invariably completely decomposed and replaced by chlorite, calcite, quartz and iron oxides. Hence the identification of the olivine depends really on the outlines of the pseudomorphs which represent it. The biotite and hornblende of these rocks are both of a rich brown colour with vivid pleochroism, and they are of comparatively late crystallisation as they often form small plates into which the ends of oligoclase laths penetrate, giving a micro-ophitic structure. Both are perfectly fresh and there is no reason to believe that they are secondary. Iron oxides are very abundant, usually octahedra of magnetite, and the rocks are stained with limonite and hematite. The structure may be described as micro-porphyritic, owing to the small size of the numerous olivine phenocrysts; many of the rocks have trachytic structure with very long narrow oligoclase crystals, arranged in winding streams; where orthoclase is abundant the crystals are shorter and broader and the structure tends to be orthophyric.

There are certain points of difference between the Skye mugearites and those of East Lothian. The latter in many cases are relatively poor in olivine, so that it is probable we should find, if the rocks were fresh, that augite and olivine were present in nearly equal abundance. Orthoclase is more common than in the Skye rocks and in some mugearites from East Lothian it is hardly less abundant than oligoclase. The scarcity of olivine and frequency of orthoclase indicate affinities to the trachytes and bostonites which occur in this district. There are, in fact, some rocks which contain little or no olivine, but consist principally of oligoclase and orthoclase felspar with decomposition products which seem to represent interstitial augite. These are hardly trachytes; neither can they be included under the mugearites according to the

definition of that group which Mr. Harker has given us. It will be sufficient for the present to recognise their existence both in Midlothian and East Lothian and that they form a connecting link between trachytes and mugearites. Many of them contain the peculiar brown hornblende and biotite which characterise the mugearites. Another distinguishing character of the East Lothian mugearites is that they are not infrequently porphytitic (Pl. Fig. 3), their phenocrysts being felspar (labradorite, $Ab_1 An_2$,—$Ab_1 An_1$), augite (idiomorphic, but invariably decomposed) and occasionally large grains of olivine.

One of the features of the mugearites of all these localities which indicates very clearly their close affinities to one another is the occurrence of biotite or hornblende of strong pleochroism, in yellow and reddish-brown colours, and having certain well-marked peculiarities in their optical properties. The biotite is present in all the three areas of distribution; hornblende has not been detected in any Midlothian mugearites, but in that district these rocks are few and badly preserved.

The biotite has the usual characters of the minerals of this group, strong pleochroism, high double refraction and (nearly) straight extinction referred to a single, very perfect basal cleavage. When scales obtained by crushing the rock are examined in convergent light they prove to be optically negative and biaxial. The most striking feature of the mineral is the great dispersion of the axes. The optic axial angle is fairly large and does not vary much. In the conoscopic field the space between the apices of the hyperbolæ (in the diagonal position) is coloured dark blue because the mineral has a much larger axial angle for blue light that for red light. This can easily be detected by examination of the axial figure in the diagonal position through blue and red glasses; in the latter case the bars are broader, less distinct and more nearly touch at their apices. Hence in white light the space between the hyperbolae is illuminated almost entirely by the blue rays and that part of the conoscopic figure is dark blue. The red seams of the concave side of the hyperbolic bars are hardly noticeable. In one flake the optic axial angle for blue light (2Eb) was 46 degrees, that for red light (2Er) 36 degrees. For the same reason thin scales of this mica in parallel polarised light when the optic axial plane is diagonal to the vibration planes of the nicols have very extraordinary blue colours, in thin scales dark azure or steel blue, in thicker scales peacock green owing to the yellow colour of the mineral itself. These features are so pronounced as to afford a ready means of identifying this mineral in rock slices. The pleochroism is X-colourless to straw yellow, Y-saffron to orange, Z-orange red to red brown, and the change of colour in cleavage plates when looked at perpendicular to the basal plane is exceptionally strong (saffron yellow to orange red when the plates are thin).

Vertical sections are nearly colourless when the light vibrates perpendicular to the cleavage. The absorption is Z > Y > X The negative bisectrix emerges slightly oblique to the basal plane. The flakes examined yielded a variety of values for the angle of obliquity owing to their being crumpled in crushing the rock but the extinction angle in clinopinakoidal sections is not above three or four degrees. Twinning on Tschermak's law is not common. A very rough six-rayed figure was seen in some of the crushed flakes; assuming it to be the pressure figure we find that this mica is of the first order as the optic axial plane is parallel to one of the rays.

A biaxial biotite resembling this one in having strong dispersion of the axes is described by Dr. Teall* as occurring in the Lentrethan porphyry of Forfarshire. Specimens of this mineral which I have examined show that the axial angle is very variable and the dispersion of the axes is of the same kind though not so marked as in the biotite of the mugearites.

The hornblende of these rocks has yellow brown to reddish brown colours and a strong pleochroism which makes it resemble the biotite very closely. Many of the sections also show no cleavage or only one cleavage and this adds to the difficulty of identification. The greatest absorption in both minerals corresponds to Z, the axis of least elasticity in the sections, and in elongated sections this is always the vibration trace most nearly parallel to the direction of elongation; lath shaped sections are positive referred to their long axes. In addition to this both minerals are very fresh and occur in much the same way, viz., as little brown crystals rarely with eumorphic shapes but moulded at their edges on the little laths of felspar which form the groundmass of these rocks. But typical cross sections showing the regular amphibole cleavage and six-sided outlines (the faces being the prism and clinopinakoid) can be found in all the rocks (Pl. Fig. 1). For the most part these minerals contain no inclusions except magnetite, and near their edges, the ends of felspar laths.

The hornblende differs from the biotite in many important respects besides the presence of two directions of cleavage and the frequently oblique extinction in sections from the vertical zone. It is optically positive, as may be proved in most cases by the use of a selenite plate with convergent light in sections perpendicular to an optic axis, or by the disappearance of the hyperbolic bars along the trace of Z in sections perpendicular to the optic normal. The optic axial angle is very large (2V about 80 degrees) and varies somewhat so that in some crystals the brush in the conoscopic field is nearly a straight one and it is very difficult to ascertain the optical sign. The dispersion of the axes is small and is the opposite of that found in the biotite (being red greater than blue). In the hornblende of the Skye rocks this can rarely be seen but some of the East Lothian mugearites contain hornblende which shows distinctly a blue fringe on the concave side of the hyperbolæ.

* *British Petrography*, p. 286 (1888).

The extinction in the vertical zone seems to attain a maximum of 20 degrees on the clinopinakoid (in sections showing vertical emergence of the optic normal figure in convergent light). In cleavage flakes the extinction angle on the prism face is 18 degrees. This corresponds very well with the values calculated by Daly* for amphiboles with 2V = 80 degrees and Z : c 20 degrees. The double refraction is much less than that of the mica; $\gamma - \alpha$ was estimated as .020. In fairly thick sections the green of the first order is just attained; in most sections the polarisation colours are red, yellow and grey. Simple or repeated twinning on the orthopinakoid is occasionally seen and the optic axial plane is parallel to the plane of symmetry. The pleochroism is X pale yellow or straw coloured, Y pale reddish brown, Z darker red brown; the tints are very like those of the biotite but the pleochroism is less intense. Absorption $Z > Y > X$. Optic orientation $X = a$, $Y = b$, $Z : c = 20$ degrees.

Mr. Harker has given an analysis of the mugearite of Druim na Criche, Skye, by Dr. Pollard, and has pointed out that it shows affinities to certain types of essexite. With this analysis we may compare that of the mugearite of Corston Quarry, Corston Hill, Midlothian, which also has been executed by Dr. Pollard. None of the East Lothian mugearites has yet been analysed. These two analyses have so great a similarity that there is no difficulty in recognising that the rocks are rightly placed in the same class. The specimen from Corston Hill is more decomposed than the Skye rock, as is indicated by the greater percentage of water given off above 105 degrees C. It contains also a rather large quantity of carbonic acid. Calculation of the mineral composition from the chemical analysis is a somewhat uncertain proceeding when secondary changes are so advanced as in this case, but it may be remembered that the felspars are in good preservation while the femic minerals are entirely replaced by alteration products. If then we allow that the carbonic acid is present as carbonate of lime and assign the remainder of the lime to apatite and felspar, we obtain the following percentages:—

| | |
|---|---|
| Anorthite ... ... ... ... ... | 13·3 |
| Albite ... ... ... ... ... ... | 42·1 |
| Orthoclase ... ... ... ... ... | 10·9 |
| | 66·3 |

This gives for the plagioclase a mean composition approximately $Ab_6An_2$, which corresponds well with that of the Skye mugearite, viz.:—$Ab_7An_2$; it forms 55 per cent. of the rock; there is 11% of orthoclase in the Corston Hill rock as compared with 12½% in the Skye rock. The differences are so small that they are for practical purposes negligible.

* Daly, R. A, *Bulletin, Soc. Minéral. France*, vol. xxii. (1899), p. 165.

One exceptional feature of the Skye mugearites to which Mr. Harker draws attention is the very high percentage of apatite; approximately 3½%, which must be regarded as extraordinary. The Midlothian mugearite is much more normal in this respect; it contains only one-sixth as much phosphoric acid as the Skye rock. Hence we can hardly be wrong in assuming that the Skye mugearite is exceptional even in its own class in this respect.

| | I. | II. |
|---|---|---|
| $SiO_2$ ... ... ... | 49·24 | 49·29 |
| $TiO_2$ ... ... ... | 1·84 | 2·27 |
| $Al_2O_3$ ... ... ... | 15·84 | 16·66 |
| $Cr_2O_3$ ... ... ... | tr. | — |
| $Fe_2O_3$ ... ... ... | 6·09 | 7·24 |
| FeO ... ... ... | 7·18 | 4·81 |
| (NiCo) O... ... ... | tr. | 0·04 |
| MnO ... ... ... | 0·29 | 0·55 |
| MgO ... ... ... | 3·02 | 2·42 |
| CaO ... ... ... | 5·26 | 5·63 |
| BaO ... ... ... | 0·09 | ? tr. |
| SrO ... ... ... | tr. | — |
| $Na_2O$ ... ... ... | 5·21 | 4·98 |
| $K_2O$ ... ... ... | 2·10 | 1·86 |
| $Li_2O$ ... ... ... | — | tr. |
| $H_2O - 105°$ ... ... | 1·61 | 0·34 |
| $H_2O + 105°$ ... ... | 1·08 | 2·11 |
| $CO_2$ ... ... ... | — | 2·32 |
| $P_2O_5$ ... ... ... | 1·47 | 0·24 |
| F ... ... ... ... | 0·18 | — |
| Cl... ... ... ... | — | ? tr. |
| S ... ... ... ... | 0·03 | nt. fd. |
| | 100·53 | 100·77 |
| Less O for F ... | 0.07 | |
| | 100 46 | |

I. (8,732). Mugearite, Druim na Criche, Skye.
II. (12,710). Mugearite, Corston Quarry, Corston Hill, Midlothian.
(Both analyses by Dr. William Pollard.)

*Summary.*—The Mugearites, a petrographical group first described by Mr. Harker as occurring in composite sills with olivine dolerite in the island of Skye, are now known to occur also among the Carboniferous volcanic rocks of East Lothian and Midlothian, where they are believed to be lava flows. In chemical and mineral composition the resemblances are very close and the group has a well marked individuality. The structure is microporphyritic and fluidal. The principal components are olivine, oligoclase, augite and orthoclase, but oligoclase forms rather more than one-half of the rocks, in long narrow prisms. The olivine occurs as numerous small grains; the augite is usually interstitial. Brown hornblende and biotite are characteristic accessories, never very abundant but probably always present. The mugearites of the Lothians show transitions to trachytes rich in oligoclase. The rocks have relatively low silica percentages, with relatively high alkalies;

this explains the association of olivine with felspars rich in alkalies as the dominant constituents of the mugearites.

Chemically the mugearites have much in common with the spilites of the Upper Devonian of Cornwall; both have low silica and rather high alkalies, principally soda; in both series of rocks there is abundance of oligoclase; the microstructure of the two groups, however, is very different and while olivine is characteristic of the mugearites it is not recognisable in any spilites which I have examined, but augite is their characteristic ferromagnesian mineral.*

## *Description of Plate*

Figure 1. Mugearite, *Leathaid Choinnich, Skye* (slide No. 9,251, magnified 47 diameters). The rock consists mainly of narrow oligoclase felspars; the dark patches are decomposition products, chiefly after olivine, and grains of iron oxide. This rock is exceptionally rich in hornblende, some of which is seen to the left near the bottom of the photograph.

Figure 2. Mugearite, *Corston Quarry, Corston Hill, Midlothian* (slide No. 12,710, magnified 35 diameters). Narrow elongated crystals of oligoclase form the bulk of the rock; there are also pseudomorphs after olivine, consisting of calcite with much limonite.

Figure 3, Mugearite. *Quarry west of West Fortun, Drem, East Lothian* (slide No. 10,829, magnified 47 diameters). One of the porphyritic types of mugearite; the large phenocryst is labradorite; the ground mass is composed of oligoclase in lath-shaped crystals, with dark patches, which are pseudomorphs after olivine and grains of magnetite. In this figure and the preceding one fluxion structure is seen.

* Flett in "Geology of the Country around Plymouth and Liskeard" (*Mem. Geol. Surv.*), 1907, p. 96.

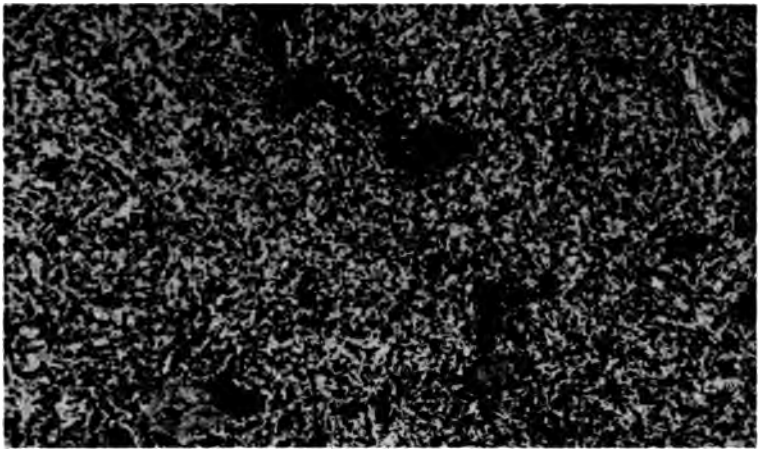

Fig. 1.

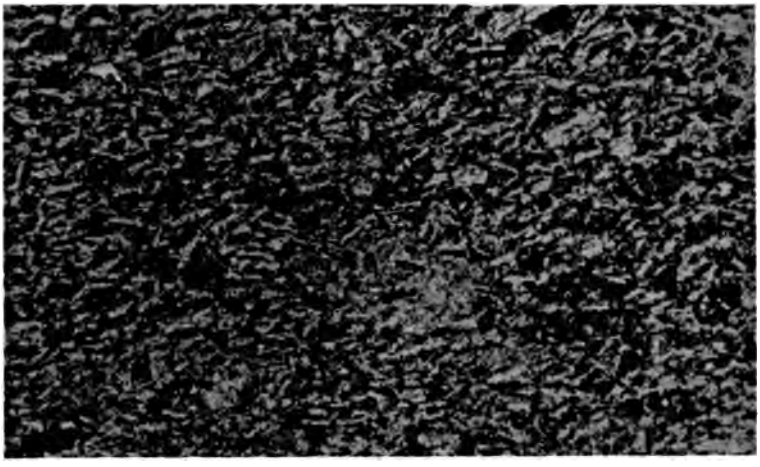

Fig. 2.

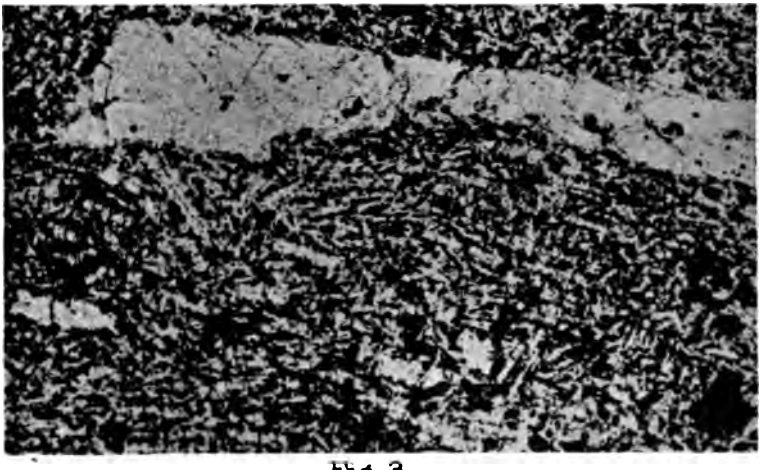

Fig. 3.

Hutt. coll.

PHOTOMICROGRAPHS OF MUGEARITES.

U.N.I.L.

## II.—The Marine Beds near the Base of the Upper Carboniferous Red Barren Measures of Scotland.

By J Smith, of Dalry, Ayrshire, and C. T. Clough, M.A.

The discovery at Palacecraig, near Coatbridge, of a marine bed near the base of the Upper Red Barren Measures of the Lanarkshire Coalfield, together with the collection in the summer, by Mr. J. Smith, of marine fossils from materials of a very similar bed sunk through at Burnockhill Pit, Ochiltree, Ayrshire, afford a fitting opportunity to put together the chief information at present possessed about the occurrence of marine beds in Scotland, near the horizon referred to. Nearly all these beds have a considerable lithological resemblance and it seems not unlikely that they are on the same horizon and may be of service in correlating the strata in the Coal-measures proper—excluding by this term the Carboniferous Limestone Coals—in the different Scottish Coalfields. This seems the more likely because marine horizons have as yet been very rarely found in these measures—differing greatly in this respect from the North Staffordshire Coal-measures in which Mr. J. T. Stobbs has described no less than eleven.* Indeed the nearest known bed to the first nine to be described in this paper must still be about 800 ft. below them† in stratigraphical position.

The localities in which marine bands have been noted near the base of the barren red measures, now amount to 10, and they are given in order from north to south, in the following list:—

*a.* Denbeath Colliery, between Methil and Buckhaven, Fifeshire.
*b.* Ravine at East Wemyss, Fifeshire.
*c.* Shore, east of Wemyss Castle, Fifeshire.
*d.* Dalkeith Park, Mid Lothian.
*e.* Drumpark Pit, about a mile and a half west of Coatbridge, Lanarkshire.
*f.* An old pit, a quarter of a mile from Drumpark Pit; supposed to be Bargeddie Pit, west of Drumpark.
*g.* The river Calder, about 500 yards south-west of Palacecraig, about two miles south-east of Coatbridge, Lanarkshire.
*h.* Burnockhill Pit, about two miles south of Ochiltree, Ayrshire.
*k.* Glen near Craigmark, Dalmellington, Ayrshire.
*l.* Grasscleuch, a mile and a quarter west-north-west of Kirkconnel, Dumfries-shire.

These localities are indicated roughly in the accompanying map, which, however, is on too small a scale to allow of "b" and "c" and of "e" and "f" being separated from one another.

The distance between the two extreme Fifeshire localities "a" and "c," is less than three miles, and Mr. J. W. Kirkby,‡

* "The Marine Beds in the Coal-measures of North Staffordshire." *Q.J.G.S.*, vol. lxi., p. 495, 1905.

† This bed was found by Mr. R. Dunlop, near Calderbank, Airdrie, in a position between the Virtuewell and Kiltongue Coals. Account of the Proceedings, *Trans. Geol. Soc., Glasgow*, vol. viii., p. 342, 1886.

‡ "On the Occurrence of Marine Fossils in the Coal-measures of Fife." *Q.J.G.S.*, vol. xliv., p. 747, 1888.

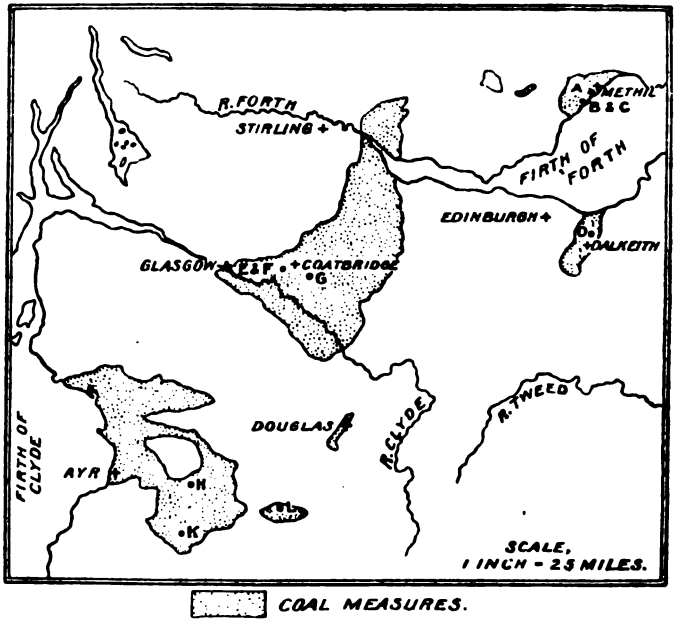


FIG. 5.—*Map showing Localities of Marine Beds near the Base of the Upper Red Barren Measures of the Scottish Coalfields.*

who first described the Fifeshire beds, appears to have been confident that they all occupied the same stratigraphical position. He also expressed the opinion that they were probably at about the same horizon as the Drumpark bed, of locality "e," which had been described by Mr. R. W. Skipsey more than 30 years before. Mr. Kirkby gives the following list of the fossils collected from the three localities:—

Plant remains, obscure.
Crinoid stems—Actinocrinus?
Lingula mytiloides *J. Sow.*
„ squamiformis *Phill.*
Orbiculoidea nitida (*Phill.*) [Discina *Auctt.*].
Productus semireticulatus, *var.* martini *J. Sow.*
Sanguinolites?
Bucania decussata (*Flem.*) [Bellerophon *Auctt.*].
Euphemus urei (*Flem.*) [Bellerophon *Auctt.*].
Murchisonia (Aclisina) striatula *de Kon.*
Discites rotifer *Salt.*
„ sp., smooth.
„ sp., with longitudinal ribs.
Orthoceras attenuatum? *Flem.*
Diplodus gibbosus *Ag.*
Mesodomodus sp. nov.
Petalodus sp.
Rhizodopsis? scales.
Strepsodus sauroides? *Ag.* teeth and scales.
Palæoniscid scales.

Mr. Kirkby also drew a vertical section in which he placed the marine bed about 260 ft. above the "Eight-foot" or Barncraig coal, and about 40 ft. below the base of the Upper Red Beds (d 5[1] of the Geological Survey). On p. 749, however, he says the bed is about 35 fms. (210 ft.) above the coal mentioned, and this seems likely to be the more correct estimate as it was repeated by him subsequently, in a note supplied to the Geological Survey.* From a section given by the Geological Survey,† it appears that the distance below the horizon adopted as the base of the Upper Barren Red Series is 70 ft.

Mr. Kirkby describes the bed in locality "a" as a shale, black, brown or rather purple, here and there with flattish concretions and cakes of soft red ironstone, which contain good examples of *Lingula*. The bed in locality "b" he speaks of as a black shale, and that in "c" as a shale, and he states that both in "b" and "c" the bed rests on a poor coal. On a visit which one of us made a few years ago to locality "c" it was seen that the marine bed was two or three feet thick, somewhat calcareous in its general matrix and not far distant from a dark grey limestone with cone-in-cone structure.

The bed in the Dalkeith locality "d," was mentioned in the Summary of Progress for 1903, p. 112. It is a dark grey calcareous band, which is exposed in several places a little above the junction of the North and South Esks. It varies a good deal from place to place, but is generally about two feet thick and includes thin lenticular bands of dark ferruginous limestone. It is in most parts more calcareous than the bed at "c," but possesses a considerable lithological resemblance to it and, like it, overlies a poor coal. In one section a dark grey limestone with cone-in-cone structure was seen just above the bed. The only fossils found are:—

**Chonetes hardrensis (*Phill.*)**
**Spirifer sp., indet.**
**Lamellibranch, indet.**
**Porcellia?**
**Orthoceras sp., indet.**

The stratigraphical position is not exactly known, but is considerably above any coals that have been worked. In the river section about 255 ft. of beds are seen below it without any workable coals, and near the bottom of these beds a bore is said to have been put down 205 ft. further without reaching any coal. It seems probable, therefore, that the bed is at least 460 ft. above the position of the Splint Coal of Craighall—the top good coal in Mid Lothian. The strata above the bed include a greater proportion of red

* "Geology of Central and Western Fife and Kinross," *Geol. Survey Memoir*, p. 155 (1900).
† *Op. cit.*, p. 148.

han those below, and have all been included in the Red Barren Series, classed provisionally, following ssil evidence procured in Fifeshire, as Middle Coal-measures.

The Marine bed in localities "e" and "f," both near Drumpark, Coatbridge, Lanarkshire, was the first above all the productive Coal-measures to be recorded in Scotland. It remained an isolated example for many years, and even now it differs in some respects from the more recently discovered beds. Mr. R. W. Skipsey described it in two papers,* and stated that the fossils occur in reddish nodules of ironstone, containing 23% of peroxide of iron, and to a less extent in a purplish red shale, a foot or a foot and a half thick, which contains these nodules. He attributed the red colour to the proximity of a fault, but this was perhaps unnecessary for the horizon must be near a stratigraphical position in which red beds are not uncommon in Lanarkshire.

He gives the following list of the fossils found:—

**Crinoid ossicles.**
**Orbiculoidea nitida (*Phill.*) [Discina *Auctt.*].**
**Productus scabriculus (*Martin*).**
**Protoschizodus axiniformis (*Portl.*).**
**Conularia quadrisulcata *J. Sow.***
**Euphemus urei (*Flem.*) [Bellerophon *Auctt.*].**

The fact that these fossils are chiefly found in ironstone nodules marks them off to a notable extent from those in the other localities, but we must remember that Mr. Kirkby also noticed in the Fifeshire bed, as already stated, concretions and cakes of soft red ironstone containing *Lingula*. From the data recorded by Mr. Skipsey it is clear that he estimated the height of the bed above the Upper Coal of Glasgow, the topmost coal which is ever worked in the pits, as 318 ft.

In the Palacecraig locality, "g," the marine bed consists of a dark grey rather hard shale, two inches thick, and an overlying dark grey ferruginous impure limestone about six inches thick. Above comes a clay-shale with nodules of clay ironstone, and below is a layer of crushed clay, two inches thick, and then a six-inch coal seam. The occurrence of coal seams just under the marine beds in Fifeshire and Mid Lothian has already been mentioned, and it may be remarked that a similar change from coals upwards to marine beds is tolerably common throughout the Carboniferous Limestone Series. Similar changes are also described by Mr. Stobbs as common in the Coal-measures in North Staffordshire.†

* "On the discovery of Carboniferous Limestone Fossils in the Upper Coal Measures to the East of Glasgow." *Trans. Geol. Soc., Glasgow*, vol. ii., p. 52, 1865; "On the Range and Occurrence of Anthracosia and other Shells in the Coal-measures Eastward of Glasgow." *Trans. Geol. Soc., Glasgow*, vol. ii., p. 144, 1866.

† *Op. cit.*, p. 516.

The Palacecraig bed is seen best in a little scar on the east side of the river Calder, about 500 yds. S.W. of (High) Palacecraig, but is also exposed on the west side of the river in a streamlet 50 yds. W.N.W. of the little scar. The bed has not yet been searched exhaustively, but from the specimens already collected by Mr. Tait the following provisional list may be given:—

**Lingula squamiformis *Phill.***
**Productus sp.**
**Posidoniella sulcata *Hind.***
**Pterinopecten papyraceus (*J. Sow.*).**
**Goniatite, indet.**
**Orthoceras sp., indet.**

In stratigraphical position the bed is probably about 250 ft. above the Upper Coal of Glasgow—which is exposed on the east side of the Calder rather more than a quarter of a mile north of the marine bed. Most of the strata between the Upper Coal and the marine bed are fairly well seen, and are chiefly of the grey and buff colours so common in the productive measures below this coal, but one of the sandstones—a thick bed, which was formerly worked in the Sweethills quarry—is reddish in parts. The strata south of, and stratigraphically above, the marine bed are less well exposed, and are perhaps affected by a considerable fault repeating some of them, but it is clear that for a height of about 120 ft. above the marine bed they are still in part of grey and buff colours. It may be mentioned in reference to these colours that Dr. Grossart* supposed a reddish colour to become general at a height of about 60 fms. above the Palacecraig ironstone. This corresponds to a height of about 400 ft. above the Upper Coal, and, according to the estimate we have just made, to a height of 150 ft. above the marine band.

The difference in lithological character between the Palacecraig bed and the Drumpark bed—which is only three miles further west—makes one doubt whether these beds are in exactly the same stratigraphical position. If they are not, it is probable that the Drumpark bed is the higher one, though the figures 250 and 318 ft., supposed to represent the heights above the Upper Coal of the Palacecraig and Drumpark beds respectively, do not differ much considering the distance between the localities. If the Drumpark bed is higher than the Palacecraig bed, it seems a little strange that Mr. Skipsey did not also find some representative of the lower Palacecraig bed in the materials brought up from the Drumpark sinking. Owing to an inrush of water, the sinking was stopped at a depth of 50 fms.—about 20 fms. below the marine bed—for a considerable time, so that there must have been particularly good opportunities for searching the material brought up from

* "On the Upper Coal-measures of Lanarkshire." *Trans. Geol. Soc. Glasgow*, vol. iii., p. 96, 1868.

above this depth. We may be sure that Mr. Skipsey was watching the sinking carefully for indications of other marine beds, for in his second paper, p. 144, he says, "I had anticipated that the further sinking of the pit would have revealed a deposit of similar fossils."

The Burnockhill No. 1 Pit (locality "h") about 2 miles south of Ochiltree, Ayrshire, was recently sunk by Messrs. Wm. Baird & Co., Ltd., Ironmasters, and for the journal of an adjacent bore we are indebted to that firm. On the bing of material brought up from the pit sinking, Mr. J. Smith found, last summer, pieces of a marine bed which has a close lithological resemblance to the marine bed, previously discovered by him, near Craigmark, locality "k", consisting, as it does, partly of a dark grey impure limestone and partly of dark shale. From the limestone he collected the following fossils:—

**Chonetes sp., very small.**
**Lingula sp., scarce.**
**Productus sp., rare.**

and from the shale he gathered the following:—

**Crinoid debris, small form, in little clusters.**
**Lingula mytiloides *J. Sow.*, a layer crowded with larger forms than in the hard band.**
**Posidoniella lævis *(Brown)*, common.**
**„ sulcata *Hind.*, common.**
**„ passage forms of above two specimens, according to Dr. W. Hind.**
**Ptreinopecten papyraceus *(J. Sow.)*, common.**
**Dimorphoceras gilbertsoni *(Phill.)*, abundant.**
**Glyphioceras micronotum *(Phill.)*, rare.**
**Orthoceras or Dentalium ?, all crushed and indeterminable.**
**Conodonts, several species.**
**Fish remains.**

The journal of the bore given by Messrs. Wm. Baird & Co., Ltd., shows a six-inch limestone about 30½ fms. above the top of the Ell Coal—the top coal generally worked in the district—and we understand this limestone is probably the bed which supplied the marine fossils collected. It is noteworthy that for 35 fms. above the limestone, and below the limestone as far down as the Ell coal, the journal makes no mention of red beds. Several coals were found in the grey measures above the limestone, but none of these appear to be workable.

The bed near Craigmark, Dalmellington, locality "k," was found by Mr. Smith some years ago, and has already been described.* The middle part is a dark grey almost black limestone about a foot thick, which occurs in a dark grey or black shale, also containing marine fossils. It is well exposed in a

* "Marine Fossils in Upper Coal-measures." *Geol. Mag.*, Decade v., vol. 1, p. 283, 1906; Account of Proceedings, *Trans. Geol. Soc. Glasgow*, vol. xii., p. 403, 1904; "Conodonts in Coal-measure Strata," *Geol. Mag.*, Decade v., vol. iv., p. 239, 1907.

glen, called the Tongue Glen on the six-inch Ordnance map, close by the middle burn of the three which unite just above Craigmark, a mile north-west of Dalmellington. The exposure is high up the glen, a little north of the crop of the Craigmark ironstone, from which it is separated by a fault hading northward. The size of this fault is not known, but it is clear that in stratigraphical position the limestone must be at least 60 ft.—it may be much more—above the Craigmark ironstone, which is above all the coals worked in the district.*

The following list shows the fossils collected from the Craigmark bed by Mr. Smith:—

Plants and vascular tissue.
Polyzoan, badly preserved.
Chonetes buchiana *de Kon.*
„ hardrensis *(Phill.)*
Lingula mytiloides *J. Sow.*
Orbiculoidea nitida *(Phill.)* [Discina *Auctt.*].
Productus semireticulatus *(Martin).*
Seminula ambigua *(J. Sow.)*, [Athyris *Auctt.*].
Pectiniform shell, ribbed.
Posidoniella vetusta *(J. de C. Sow.).*
Dentalium?
Murchisonia striatula *de Kon.*
Goniatites, crushed.
Nautiloid shell.
Cladodus.
Coprolites and fish remains.
†Centrodus lineatus *Pander.*
†Polygnathus mosquensis (*Pander*) [Gnathodus *Auctt.*].

All the forms, except the Conodonts, are dwarfed.‡

Regarding the bed at Grasscleugh, locality "1," a mile and a half north-east of Kirkconnel, Dumfries-shire, our knowledge is but scanty. It was discovered many years ago by Mr. Macconochie and consists of a dark grey calcareous shale or shaly limestone, about a foot thick. The stratigraphical position is above most of the workable coals of the Sanquhar coalfield, but it is not clear that it is above the two topmost—the Calmstone and the Creepie—the interval between which

* Mr. James Prentice in his account of "The Mineral Seams of New Monkland," *Trans. Fed. Inst. Min. Engineers*, vol. xii., p. 448, 1896, correlates the Upper Coal of Glasgow with an Ayrshire seam which occurs 100 ft. below the Craigmark ironstone.

† "Conodonts from the Carboniferous Limestone strata of the West of Scotland," by John Smith. (With Notes on the specimens and Descriptions of six new species, by G. J. Hinde). *Trans. Nat. Hist. Soc. Glasgow*, vol. v. (New Series), p. 336, 1900.

‡ It should be added that a limestone pierced in a bore near the Barony Pit, nearly a mile and a half west of Auchinleck, Ayrshire, may possibly be in the same position as the Burnockhill bed, but no core of this Barony limestone has been seen by us. In this bore, for the journal of which we have again to thank Messrs. Wm. Baird & Co., Ltd., the limestone is 51 fms. above the top of the Ell Coal, and the position of a plant bed with Upper Coal Measures plants, described on p. 112 of this year's Summary, appears to be about 1,075 feet above the limestone.

is only seven fathoms.* The fossils which have been collected from this bed are as follows:—

Lingula sp., small.
Posidoniella sulcata *Hind.*
Pterinopecten papyraceus *(J. Sow.).*
Glyphioceras sp. indet, abundant but crushed.
Orthoceras sp. indet.

The title of Mr. Skipsey's first paper emphasises the fact that the fossils in the Drumpark bed are not only marine, but also, as far as could be judged, specifically the same as those found in the Carboniferous Limestone more than 300 fms. below. Much advance has been made in palæontology since this paper appeared, but it seems true still that very little perceptible difference can be detected between the forms in the marine beds which have been described and those in the Carboniferous Limestone Series. On this question Dr. Lee has kindly made the following remarks:—

"The collection of fossils in the possession of the Geological Survey is at present not extensive enough to allow one to draw general conclusions as regards the distribution of species; yet the occurrence of *Posidoniella sulcata* and *Pterinopecten papyraceus* in three of the localities (viz., Dalmellington, Palacecraig, and Burnockhill) is to be noted. The Brachiopoda, although poorly preserved, seem to have a constant habit, the most interesting feature about them being the fact that many of the forms are dwarfed. As regards vertical distribution, with the exception of *Posidoniella sulcata*, there does not seem to exist any specific difference between these forms and those occurring lower down in the Carboniferous Limestone Series; even the Cephalopoda seem to make no exception. *Glyphioceras micronotum* and *Dimorphoceras gilbertsoni*, found by Mr. J. Smith at Burnockhill, have also been described by Dr. Wheelton Hind from the North Staffordshire Coalfield and other Coal-measure localities in England. It is a most interesting fact, inasmuch as these two species have not long ago been found by Mr. D. Tait in the upper part of the Calciferous Sandstone Series of Fifeshire, near Inverkeithing.† This tends to prove that the

Since the above was written, Mr. A. Wilson, Manager of the Kirkconnel Colliery, has found this marine bed in another locality, namely, in Pobower Burn about 830 yds. north-west of Kirkconnel Station. The new locality is near the site of a bore, which was put down some years ago under the direction of Mr. D. Russell, Manager of the Sanquhar and Kirkconnel Collieries Co., Ltd., so that we are now, by means of the information kindly supplied by Mr. Russell, enabled to fix the stratigraphical position of the bed. This position is about 34 fms. above the Creepie coal—the highest seam worked in the Sanquhar coal-field.

Mr. Wilson states that the bed overlies a thin coal, and in Pobower Burn is markedly lenticular, varying from 7½ ins. to 2½ ins. in thickness in the distance of a yard. Parts of it show "cone-in-cone" structure both in Grasscleugh and Pobower Burn.

† Summary of Progress for 1905, p. 145, and Proceedings *Geol. Soc. Edinburgh*, December, 1907.

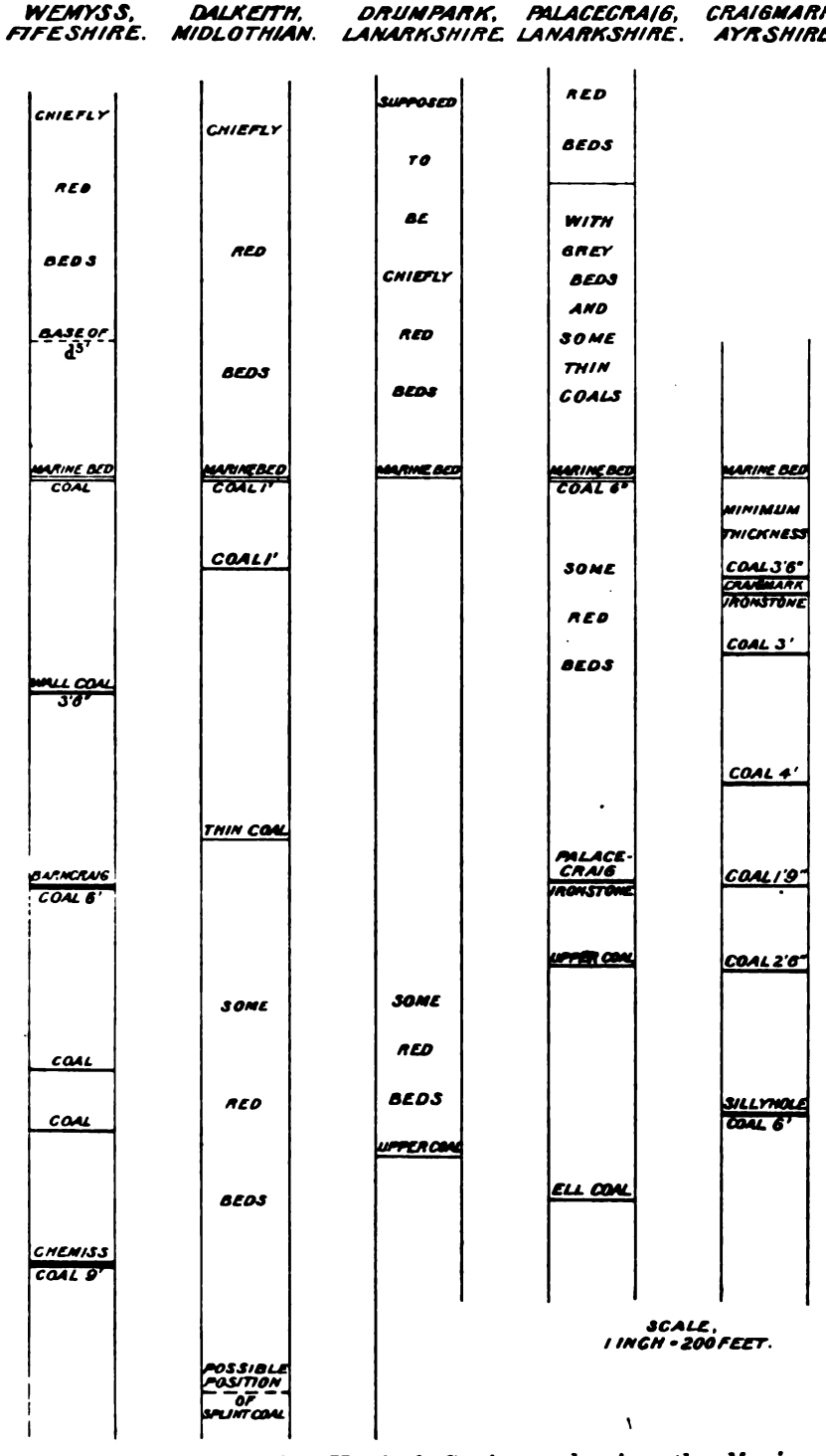


FIG. 6.—*Comparative Vertical Sections, showing the Marine Beds near the base of the Upper Carboniferous Red Barren Measures of Scotland.*

vertical range of these two species is far wider than hitherto supposed, and a comparative study of a number of specimens from the highest and lowest horizons respectively might bring some interesting points to light, as regards the question of evolution in this class of fossils."

In order to summarize our present knowledge regarding the stratigraphical position of the best known of the marine beds described, we have drawn up five vertical sections, which show the probable position of these marine beds with reference to underlying well-known coal-seams in the Counties of Fifeshire, Mid Lothian, Lanarkshire and Ayrshire. Some information about the prevalence of red measures is also given in these sections, but it must be remembered that we are unable to speak confidently about the meaning of their red colour. It seems probable that this colour is sometimes original and sometimes acquired by secondary staining.

## III.—The Eastern Extension of the Nottinghamshire and Yorkshire Coalfields.

By Walcot Gibson, D.Sc., F.G.S.

During the re-survey of the Derbyshire and Nottinghamshire coalfield the opportunity has been taken to examine the material passed through in the new sinkings and borings in the neighbourhood of this coalfield, and in that of the sister-coalfield to the north.

These borings and shafts lie between Selby and Nottingham, and between the outcrop of the Magnesian Limestone on the west and the Lias on the east. That is, they are situated in an area in which it is generally admitted that the underlying unwrought coal constitutes a most important part of the national coal reserve. Their situation is shown on the accompanying sketch map (Fig. 7 p. 138). The probable shape and general structure of this concealed and virgin coalfield has been dealt with by Professor P. F. Kendall in the Final Report of the Royal Commission on Coal Supplies, 1905 (part ix., pp. 18—33). As, however, some of the borings and sinkings are not yet completed, while others which will yield further information are to be commenced, we shall limit ourselves to the mention of some salient results obtained from the examination of the new material, and shall not touch upon the big problem of the structure of the concealed coalfield.

Among the chief results obtained are (1) an increased knowledge of the thickness and character of the cover formed by the Trias and Permian formations, and (2) the determination of the approximate horizons in the Coal-measure sequence on which the red rocks unconformably repose.

For convenience of reference we give the sub-divisions of the Trias and Permian for the area under consideration, with their minimum and maximum thickness, and also the thickness of the Grey-measures above the Top Hard Coal, or its Yorkshire equivalent, the Barnsley Coal;—

| | | Feet. |
|---|---|---|
| Trias | Keuper Marl ... ... ... ... ... | 700 to 850 |
| | Keuper Waterstones... ... ... ... | 140 to 740 |
| | Bunter ... ... ... ... ... ... | 180 to 621 |
| Permian | Upper Permian Marl ... ... ... | 0 to 90 |
| | Upper Permian Limestone ... ... ... | 0 to 50 |
| | Middle Permian Marl ... ... ... | 20 to 140 |
| | Lower Permian Limestone and "Marl Slates" | 50 to 270 |
| Coal-measures—Grey Coal-measures to Top Hard Coal | | 1000 to 1670 |

The thickness ascribed to the Keuper Waterstones is often an uncertain quantity, since it is difficult to separate this subdivision of the Keuper from the Marls above and from the Bunter beds below.

(1) All the borings and shaft-sinkings here dealt with commence below the Lias, and do not therefore give the maximum

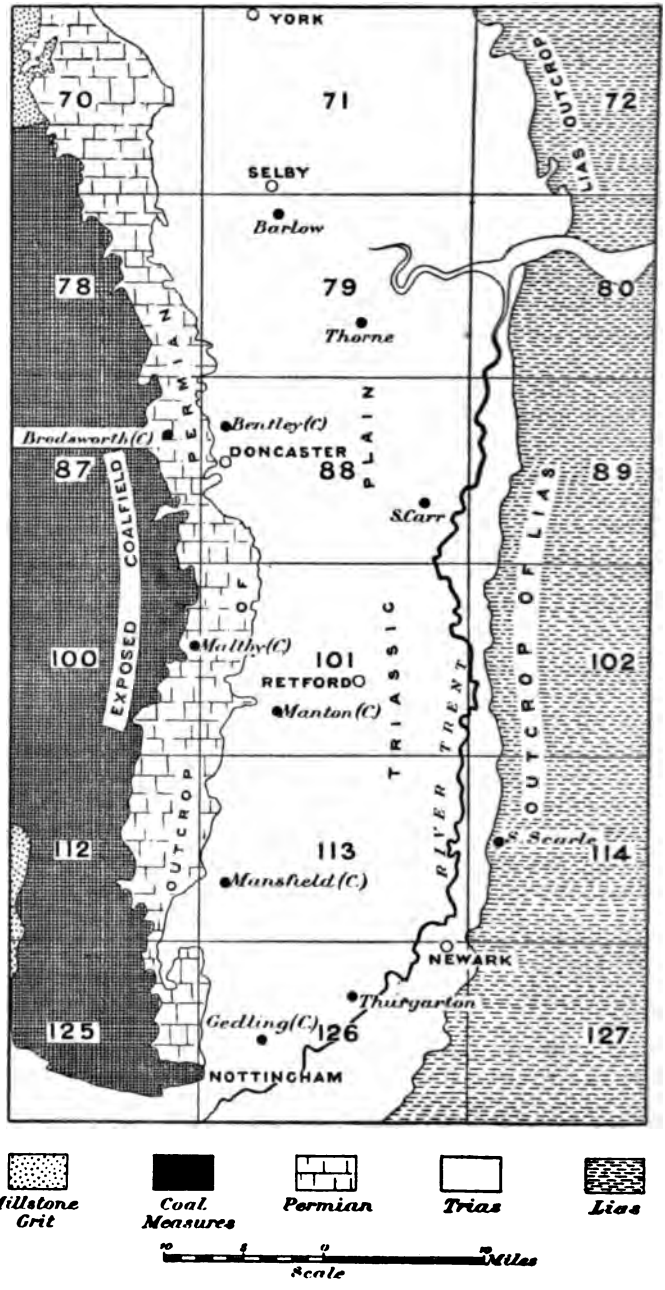


FIG. 7.—*Sketch-map showing the position of Borings and Shaf between Selby and Nottingham.*

thickness of the Keuper, but many of them pass through the entire thickness of Bunter. In the Selby (Barlow) boring situated at the extreme north of the area under discussion the Bunter formation is 620 ft. thick, and at Gedling, near Nottingham, it is 180 ft. thick. Taking the Permian, the thickness at Selby amounts to 545 ft., and only 47 ft. at Gedling. It would appear, therefore, that the Bunter and Permian formations diminish along a general north and south line at about equal rates; but it is found that on a north and south line taken further east, toward the centre of the basin, the Permian maintains a uniform thickness of a little over 500 ft. between Scarle and South Carr, but rapidly diminishes in thickness to the south of Scarle. The well-known easterly increase follows the same rule. Traced eastward from the outcrop the increase is at first rapid, but the Permian soon attains a maximum development, and remains at this thickness up to the limits of the most easterly boring of which we have any information. In the deeper borings and sinkings the Lower Magnesian Limestone tends to become highly fossiliferous, and at Bentley Colliery the fossils represent fully-grown forms very unlike the dwarfed species obtained from nearer the outcrop.

(2). At Gedling the Permian rests on the Etruria Marls, and at Thurgarton on the Keele Group; but over the remaining area, except at Maltby and possibly at Scarle (for it is not safe to draw definite conclusions as to the horizon reached from about 10 ft. of Coal-measure strata in a boring of which the core was only 0.9 inch in diameter), repose on lower horizons in the Coal-measure sequence. If the Etruria Marls are taken as forming the base of the Upper Coal-measures, it appears from the occurrence of *Anthracomya phillipsi* in the reddish shales below the Permian that the Selby boring entered the Coal-measures at an horizon only a few feet below the base of the Etruria Marls.

All the other sinkings and borings examined reach the Coal-measures at a slightly lower horizon that at Selby, but in all cases nearly the full thickness of the grey-measures above the Barnsley Coal is present. It would be premature to draw any definite conclusion from the presence of nearly the full thickness of grey-measures over the large area here dealt with, since the borings and sinkings lie at widely-separated intervals. It is safe, however, to assert that the Top Hard Coal lies at workable depths between the Trent and the outcrop of the Magnesian Limestone, but what that depth will actually amount to at any particular spot or what will be the quality and thickness of the seam can only be settled by actual trial.

In a previous SUMMARY (for 1905, pp. 21 and 77) mention was made of a marine band, very rich in fossils, found at a distance of 630 ft. above the Top Hard Coal at the Mansfield Colliery. The same bed occurs at 705 ft. above the Barnsley Coal in the Brodsworth and Bentley Collieries, near Doncaster, where we have had the advantage of the active co-operation of

Mr. H. Culpin in examining the material obtained in these new sinkings. The fauna in the bed is similar, though perhaps not so rich in species, as in the bed at Mansfield; and the similarity is emphasized by the presence at both localities of the rare ichthyodorulite, *Listracanthus wardi*. An argillaceous limestone, containing the characteristic fossils of the zone, forms the base of the horizon both at Brodsworth and Bentley. In addition to the bed 705 ft. above the Barnsley Coal, Mr. Culpin has found at Brodsworth:* (1) a bed containing *Goniatites*, *Pterinopecten*, *Posidoniella lævis*, *Nuculana acuta*, which is possibly the one mentioned by Green† as lying 100 ft. below the Ackworth Rock in the neighbourhood of Pontefract; (2) a bed with *Pterinopecten* and *Lingula* 382 ft. above the Barnsley Coal; and (3) a bed with only *Lingula*, 111 ft. above the Barnsley Coal.

[Since this was written the Barnsley coal 9 ft. thick, has been proved in the Thorne boring at a depth of 916 yards, and at Bentley Colliery at a depth of 620 yards.]

* "The Naturalist," No. 613, February, 1908, pp. 39-40.
† "The Geology of the Yorkshire Coalfield," *Mem. Geol. Surv.*, 1878, p. 471.

## IV.—The New Great Western Railway from Ashendon to Aynho, near Banbury.

By George Barrow, F.G.S.

An examination has been made of the sections laid open in the formation of the new line of railway, connecting the Great Central and Great Western Railways from Ashendon, east of Brill, through Bicester, to Aynho, south of Banbury, in Oxfordshire. The direction of the route is from south-east to north-west, roughly across the line of strike of the rocks, thus affording the maximum amount of information in the shortest distance, and throwing most light on the structure of the area traversed. In the course of our investigations we received much assistance from Mr. Robert C. Sikes, M.Inst.C.E., the engineer acting for the Great Western Railway.

At the south-eastern end of the line is the Ashendon and associated range of outlying hills, rising to over 500 ft. above sea-level, and formed mainly of Portland Beds; near the north-west end is the escarpment of the basal beds of the Oolite, attaining a height of about 450 ft., and overlooking the Cherwell Valley, which is formed mainly of soft Liassic shales. Between the two eminences, some 16 miles apart, the intervening and lower ground is broadly divisible into two portions, a limestone area and a clay area, the dividing line passing close to Bicester. To the north-west of this town the Cornbrash and Great Oolite limestones cover the greater part of the surface of the ground, forming an essentially dry soil; to the south-east the surface is composed of the Oxford and Ampthill Clays, and the ground is damp and in part almost waterlogged. The clay area is, moreover, divided into two parts by a chain of outcrops of the drier Cornbrash, which forms a ridge traversed by the new railway at Blackthorn Hill, to the south-east of Bicester.

As level crossings are now practically prohibited, the roads in the low-lying area have to be crossed by bridges connected by long embankments, and though these cover much of the ground and obscure the geology, yet elsewhere an exceptionally large amount of material has been extracted from the cuttings to supply these banks, and the sections are long and deep.

### The South-eastern or Clay Area.

#### *Ashendon to Wotton Park.*

During the previous examination of the cuttings on the Great Central Railway, near Ashendon, an anticline was noted by Dr. A. Morley Davies, close to the point where the new line starts:* this brings up the Oxford Clay from beneath the Amp-

* See *Proc. Geol. Assoc.* vol. xx. p. 184.

thill Clay, and suggests that the flat ground in the direction of the dip is composed of the higher beds. This view is strengthened by the occurrence of an old excavation (cattle pond) along the route, from which a great quantity of *Exogyra nana* had been obtained; the pond lies due north of Dorton, and the material dug out of the pond was cut open when the ground was bared for the embankment. Some 600 yards further to the north-west is the first cutting; in this the beds consist of dark clay containing a number of paler hard sandy clay-bands (stone-bands), which are probably somewhat calcareous at a depth below the surface. The darkest and most tenacious clay occurs at the northern part of the cutting, and a stone-band in it contains at its base a number of isolated specimens of *Ostrea discoidea*. This clay is separated from the beds further south by one, if not two, small faults, beyond which the clay is distinctly less dark; the lowest stone-band in this part of the sections occurs only at the south end of the cutting, and immediately below it the same *Exogyra* is extremely abundant, and marks almost certainly the same horizon as at the pond. Thus the whole of the beds in this first cutting appear to belong to the Ampthill Clay.

This section brings out clearly the structure of this part of the district which consists of a number of small anticlines and synclines broken by minor faults. As the Exogyra band here is rising to the south there must be a small anticline between it and the pond, and a small inlier of Oxford Clay may be present though it has not been detected: briefly, this part of the line traverses the Ampthill Clay with possibly a few minor inliers of Oxford Clay.

*Rushbeds Wood, west of Wotton Underwood.*

Some deep excavations and a tunnel are being made at Rushbeds Wood, north of Wood Siding Station on the Brill tramway; the excavations for the bridge are in dark tenacious and unctuous clay with abundant fossils at the base. These are difficult to extract, but sufficient were obtained to show their Ampthill Clay age. In the tunnel part of the beds belong the same horizon, but the Oxford Clay is said also to have been met with; it probably does not reach the surface, and at the point north of the wood where the tunnel emerges, the same *Exogyra*-bed is twice met with. In the more northerly outcrop it appears to pass under undoubted Oxford Clay, a deception that is due to the effect of a reversed fault clearly seen when the face of the cutting was fresh. This fault marks the termination of the Ampthill Clay, as it does not occur again further north-west. In this direction the Oxfordian age of the beds is clearly shown by the abundance of the typical *Gryphæa dilatata* with the large beak, strongly incurved and with a tapering point. Two points of additional interest were noted here; first the "Race"* which may occur to some extent

* Concretions of carbonate of lime, often septarian.

in any part of the section is far more abundant near the surface, and can be seen clearly to be due in large part to surface agencies; it is produced by the alteration of calcareous material within the rocks, and in one case Mr. Woodward and myself found a fossil in process of being converted into race. Secondly, on the top of the cutting at one point are some small patches of gravelly drift, not, however, true Boulder Clay but rather of the nature of the Head of the south-west of England; it contains fragments of Shotover ironstone, and appears to have travelled down the slope of what may be conveniently called the Brill area, when the ground was less denuded than at present, for now there are intervening hollows that would make such a course impossible.

There is another belt of comparatively flat ground to the south-west of Ludgershall in which no sections occur; it is composed of Oxford Clay, for in stripping off the grass many fragments of the typical large *Gryphæa* were found, shells which have resisted decomposition and dissolution. In addition, fragments of sandy ironstone are numerous, and point to the former extension of much higher beds that have been since removed by denudation.

### *Ludgershall Cutting.*

Due west of Ludgershall a cutting has been made in less tenacious clay which also contains "stone-bands." The most southerly portion of the cutting contains a great number of shells of *Gryphæa*, identical in form apparently with *G. dilatata* but much smaller. This portion is separated by a small fault from the rest of the cutting, in which two stone-bands occur, the upper being characterised by the extraordinary abundance of Ammonites in it. These rarely retain any part of their original shell; they are often broken, the parts slightly sundered, and most are somewhat flattened. It seems as if there had been a specially favourable environment for the growth and development of these molluscs, which clearly lived to a good old age and died here. So slowly did sedimentation proceed that the shells were partly dissolved away, becoming so thin that they fell asunder or were flattened with the slightest pressure. That the abundance of the Ammonites and their large size is due to favourable conditions seems clear, for though Ammonites are abundant both above and below the band, they are all quite small and in many cases seem identical with the inner whorls of some of the larger species of the Ammonite bed; as, however, the shells are not preserved it is not easy to make sure of this point.

### *Ludgershall to Blackthorn Hill.*

Between Ludgershall cutting and Blackthorn Hill, a distance of three miles the line crosses another flat, and in

this case partly water-logged area, in which no good sections occur. In building the foundations of bridges, and in constructing new ponds to replace those covered by the embankment, excavations have been made in some rather more sandy clay, which is distinctly poor in fossils, even allowing for dissolution near the surface. In one case only were traces of fossils found and these were mostly small; indeed, only in the case of a *Cardium* could the genus be determined. There is no true lithological representative here of the Kellaways-rock, though the horizon probably is present.

### *Blackthorn Hill.*

Although the cutting at Blackthorn Hill is not quite completed, it has proceeded far enough to show the real structure of the ground, and expose a complete section of the Forest Marble group and the greater part of the Cornbrash. The structure of the hill suggested by the published map is a simple anticline of Cornbrash rising on both flanks naturally from beneath the Oxford Clay. This is the view naturally taken in the absence of sections, for both the top and flanks of the hill are entirely covered with the débris of the Cornbrash. The deep cutting, however, shows that the rubble at the surface on the flanks of the hill is not really derived from the underlying rock *in situ*, but has been washed down from the hill-top, and forms a kind of skin of "wash" which gives no indication of the rock beneath it. Although the latter is Cornbrash over most of the hill, at two points it is not; at the first there is a small outcrop of the Forest Marble group; at the second the underlying material consists of dark tenacious clay associated with some incoherent sand, both of Oxford Clay age. In both cases these newly-found outcrops abut against small faults, remarkable for their low hade, though they are not reversed; while the beds between the two faults are violently contorted. The structure of the hill is clearly brought out by the accompanying section (Fig. 8). At the foot of the hill on the south-eastern side several small openings have been made, which pass through a few feet of Oxford Clay to the top of the underlying Cornbrash, and the position of the latter has thus been accurately fixed.

As the hill is ascended it is seen that the slope is not as steep as the dip of the beds, so that on the hill-top only some 5 ft. of Cornbrash is left, the rest having been denuded away. About this point the beds become horizontal, and thus continue for some yards down the other side of the hill, so that the base of the Cornbrash actually outcrops beneath the rubble previously referred to, and for a few yards the rock *in situ* consists of the upper beds of the Forest Marble group. The first small fault then throws the beds down to the north-west about 10 ft., and brings on the base of the Cornbrash again, Further on this outcrop is displaced by the second fault, that

throws down the Oxford Clay against the middle of the Cornbrash.

The cutting at the first fault is fortunately just deep enough to expose the top of the Great Oolite Limestone, easily identified over the whole of this area by its peculiarly compact pale "cream-cheese" like top; and as the base of the Cornbrash caps the cutting only a few yards off, a complete vertical section of the Forest Marble is exposed here, the details of which are given in the subjoined table.

*Section of Beds in the Cutting at Blackthorn Hill.*

| | | Ft. | in. |
|---|---|---|---|
| 4. Cornbrash. | Lower part only. Rubbly, shelly, non-oolitic limestone ... ... ... ... ... ... ... | 5 | 0 |
| Forest Marble | 2e. Sandy clay, with one pale marl-band .. ... | 3 | 6 |
| | 3c. Hard grey oolitic limestone ... ... ... | 1 | 6 |
| | 2d. Dark tenacious clay, passing down to lighter clay, with three pale marl-bands ... ... | 7 | 0 |
| | 3b. Pale grey blotchy limestone ... ... ... | 3 | 6 |
| | 2c. Pale clay parting ... ... ... ... ... | 0 | 6 |
| | 3a. Hard clay-limestone ... ... ... ... | 1 | 9 |
| | 2b. Pale grey clay ... ... ... ... ... | 0 | 6 |
| | 2a. Bright bluish-green clay passing down into grey clay with (?) phosphatic nodules ... | 3 | 6 |
| 1. Compact top of the Great Oolite Limestone ... ... ... | | — | |

Several points in the section are worth noting. First, nearly all the beds given above are grey (darker or lighter) if fresh and quite free from decomposition, and their true character is then difficult to make out; the admixture of a large amount of clay with the limestones is a usual feature of the Forest Marble group.

The *Terebratula*-bed close to the base of the Cornbrash is fairly well seen here; but it is rather sporadic, and not so well developed as in the ground to be described later. The non-oolitic character of the Cornbrash, pointed out by Mr. Woodward, is a valuable distinctive feature in tracing the outcrops on the ground.

The lower part of the Forest Marble is more sandy, and the limestones less pure and oolitic in the lower part of the group than in the area to the north-west of Bicester; they seem also to be a few feet thicker. The peculiar hard pale marl-bands are more developed at Blackthorn; they give the impression of not containing much lime, but they are burnt for manure in a kiln close by. Fossils are rare in these bands; a few casts of *Lima cardiiformis* (?) and some green-stained rootlets being met with occasionally. The intensely green band No. 2*a* is worth noting, for even in a hand-made boring it could scarcely be missed, and thus marks a well-defined horizon. A feature of the Forest Marble here is the large amount of fossil wood found in it, especially at the horizons 2*c* 3*b*. In a brickfield close by a large number of fragments have been found in the highest clay bed, one of which was as thick as one's arm, and 9 ft. long.

5. Clay and sand ... KELLAWAYS BEDS.
4. CORNBRASH.
3. Limestone-bands
2. Clays and pale marl-beds ... } FOREST MARBLE.
1. GREAT OOLITE.

FIG. 8.—*Diagram-Section across Blackthorn Hill, East of Bicester.*

### *Blackthorn Hill to Bicester.*

From Blackthorn Hill to Bicester, a distance of nearly two miles, the Oxford Clay forms another rather low-lying flat in which exposures are rare; a few new cattle-ponds have been made, but the clay taken out is greatly decomposed. A small test pit was sunk to the west of Launton, penetrating the lower beds of the Oxford Clay, which are darker, softer, and more tenacious than the middle portion. Close to the side of the London and North-Western Railway a small pit fixes exactly the position of the top of the Cornbrash. This starts at O.D. 230.8 and penetrates 5 ft. of clay, yellow at the surface but darker below, and then enters the top of the Cornbrash, which is here a rather greenish rock; it contains numerous fossils, a *Trigonia* being specially common.

## THE NORTH-WESTERN OR LIMESTONE AREA.

### *Bicester to Bucknell.*

To the north-west of the pit just referred to the country consists essentially of limestone, the interbanded shaly or marly strata making quite an insignificant appearance at the surface. There are three of these limestones present in the area; (1) the Cornbrash; (2) the Forest Marble; (3) the Great Oolite Limestone. The first and third cover the greater part of the area, though over considerable tracts they form little more than a skin, as is clearly shown in the new cuttings.

(1.) The Cornbrash, which as before mentioned, is easily distinguished in this area, forms a great spread and the

skin-like manner of its occurrence is well shown about the water-tower west of Bicester, where all the quarries extend through the basal bed into the underlying Forest marble; indeed, the quarries have really changed the old geological survey map, for every opening has converted a Cornbrash area into a Forest Marble area. The old map brings out the shallow nature of the outcrop, for all the small hollows, in which the local streams flow, are apparently narrow inliers of the lower beds. In the ground about the water tower the whole of the Cornbrash is never seen and its exact thickness is not ascertainable.

(2) The Forest Marble consists of alternations of clay and sandy clay with markedly oolitic thin limestones, all in this area characterised by a grey tint, if not decomposed. The latter contain numerous fossils, though the number of species seems rather restricted. The oolitic structure of these limestones proves of the greatest assistance in separating them from the Cornbrash when both are weathered. The cuttings have brought out well the rapid variation in thickness of the component members of the Forest Marble group; the bands are markedly lenticular so that in a long cutting it is impossible to add together the different components and obtain a sequence, the details of which would be strictly applicable at any one point. The total thickness of the group does not however seem to vary much and is between 17 and 20 ft.

(3) The Great Oolite Limestone when first cut open gave the impression of a great mass of limestone, of fairly uniform composition, in which two persistent partings occur, each about three feet thick. Exposure to the atmosphere during a wet season accompanied by several sharp frosts has completely changed the aspect of the rock. It is now seen to consist of a great number of rigidly parallel bands of fairly pure greyish and shelly oolitic limestone which rarely exceed a foot in thickness and are often less, each of which at its margin passes gradually to a more clayey limestone of a pale pinkish yellow tint. Midway between each purer band the rock becomes at last more of a marl than a limestone, and this portion has in all cases been disintegrated by frost and rain and weathered out to the depth of an inch or two. A series of rigidly parallel recesses in the face of the cutting have thus been produced, between which the cores of purer limestone project. The whole gives an ideal example of parallel bedding or even-deposition, strongly contrasting with the overlying Forest Marble. In the purer limestones the shells are preserved and their broken edges are seen on the face of the rock, but in the more clayey portions the fossils seem mostly casts; the latter, however, are at times extremely numerous as the blocks in the great embankment clearly show. Certain species occur along definite

lines in great abundance; for example there is a *Trigonia*-bed about 10 ft. down in the limestone, but the specimens are all casts and the rock has been so shattered by dynamite that an apparently sound fossil broke to pieces before it was carried home.

The two persistent clay bands, while retaining their usual thickness of about three feet, vary greatly in composition, passing from a markedly calcareous clay to a dark grey clay; the higher band in one place contains in its centre a thin film of lignite about one-eighth of an inch thick and about 10 yds. long, as seen in the cutting. These persistent partings are of great service, as the details of the beds between them can be added together and the thickness of the whole Great Oolite Limestone obtained; this is about 43 ft.

The great embankment already referred to crosses the flat ground, composed at the surface entirely of Cornbrash, that lies to the north-west of the Bicester water-tower, and terminates at the foot of the small slope due south of Bucknell. Here the great cutting begins from which the material has been obtained to build the embankment. This cutting is practically four miles long and terminates in a tunnel, and when the whole is finished there will be a complete section of all the beds from the base of the Cornbrash to the middle of the Upper Lias. The work falls naturally into three sections; first that from Bucknell to the north side of Ardley Wood; second, from the latter to the tunnel, and third the tunnel itself.

### *Bucknell to Ardley Wood.*

This portion of the work is 4,000 yds. long and cuts through the whole of the Forest Marble, the whole of the Great Oolite Limestone, and exposes a few feet of the underlying Estuarine Series.

For 1,500 yds. the Forest Marble is exposed in the cutting and all its characters can be accurately studied, as the false-bedding and lenticular nature of the grey oolitic limestones are clearly shown. For a distance of about a thousand yards the surface-layer of the first part of the cutting is formed by the base of the Cornbrash, in which the *Terebratula-intermedia* bed is well developed. Owing to the rubbly nature of the rock, the fossils fell out when the cutting was first made and rolled down to the base of it where they could be at times gathered in handfuls; a number have been collected and will be determined in due course.

The Cornbrash leaves the top of the cutting a little north-west of the Bucknell Road, and here the exact outcrop of the rock is accurately fixed. A little beyond this point the top of the Great Oolite Limestone comes to the surface at the base of the cutting, and the two points are sufficiently near for an approximate measurement to be made of the total thickness

of the intervening Forest Marble, the details of which are as follows in descending order:—

| | Ft. | in. |
|---|---|---|
| 1. Base of Cornbrash ... ... ... ... | — | |
| 2. Yellow grey clay ... ... ... ... ... | 3 | 0 |
| 3. Yellow sandy limestone (grey unweathered) ... | 2 | 6 |
| 4. Yellowish grey clay ... ... ... ... | 1 | 3 |
| 5. Markedly oolitic grey limestone ... ... | 1 | 0 |
| 6. Grey clay ... ... ... ... ... ... | 2 | 0 |
| 7. Grey bedded limestone ... ... ... ... | 2 | 6 |
| 8. Grey shaly clay. ? All seen ... ... ... | 5 | 0 |
| 9. Compact top of Great Oolite Limestone ... | — | |
| Total ... ... ... ... ... | 17 | 3 |

The beds given above are not all visible in any one place, but are sufficiently close together to prevent a mistake in the total of more than a foot or so. The basal band is obscured now by downwash, and there may be a thin band of limestone in it.

The rocks are more calcareous on the whole than at Blackthorn Hill; the lignite or fossil wood so common there is distinctly rare here, and none was noticed and none has been found, so far as could be ascertained.

The outcrop of the Great Oolite Limestone referred to above is a small isolated patch at the crest of a very low anticline; the main outcrop is first met with about 100 yds. beyond the small hollow that forms the only break in this great continuous cutting. Here for a few hundred yards the limestone is capped and protected by the basal clays of the Forest Marble, and consequently undecomposed. The top of the whole consists, as already stated, of a pale compact rock without oolitic grains or visible fossils; from its appearance it has been called the "Cream cheese" top, and is certainly one of the most valuable lithological horizons in the whole area. This character is maintained for about two feet, when it slowly changes downwards to the pale pinkish-yellow type so common in the rest of the bands. The whole, however, weathers as one solid block, and there are no well marked projecting purer bands in it. This portion may thus conveniently be called the "first block" and is seven feet thick.

Below this comes the first continuous clay parting, three feet thick already referred to, and here the thin film of lignite occurs. Just before the base of this band appears, the Forest Marble at the top of the cutting ends, and for a mile and a half the sections are exclusively in the Great Oolite Limestone.

The "second block" is about 18 ft. thick and is composed of a number of the purer limestone bands, alternating with more clayey portions, the whole showing well the parallel bedding and the singularly even deposition that characterises the rest of the strata. About two feet down in this block is a nine inch band of limestone like the "Cream-cheese" rock,

but not quite so compact. Beneath it fossils are very abundant and a good number can be fairly well extracted. The base of the whole block is a siliceous limestone from which the shells dissolve out leaving a curiously porous rock, which by its occurrence enables the next underlying continuous clay parting, three feet thick, to be at once identified. This parting forms practically the base of the cutting for about a mile, after which it slowly rises till it reaches the top, and the base of the clay outcrops only a few yards short of the road at Ardley Wood. Fortunately, at this very point, the cutting has laid open the first few feet of the Estuarine beds, so that the "third block" of the Great Oolite is exposed in one vertical face; and its thickness being 12 ft., by adding together the measurements of the components the thickness of the whole is obtained, the details of which are shown below.

*Section of the Great Oolite Limestone about Ardley.*

| | Ft. | in. |
|---|---|---|
| 1. Basal clays of the Forest Marble. | | |
| 2. "Cream Cheese" limestone 2 feet, passing gradually to the ordinary clayey limestone ... ... ... ... ... ... | 7 | 0 |
| 3. Persistent parting of calcareous clay changing locally to grey clay. Lignite film at one point ... ... ... ... ... | 3 | 0 |
| 4. Hard clayey limestone passing at base to pale compact limestone ... ... ... ... ... ... ... ... ... ... | 2 | 0 |
| 5. Alternations of pure and clayey limestone. Fossils abundant at top ... ... ... ... ... ... ... ... ... ... | 5 | 8 |
| 6. Alternations of pure and clayey limestone; this part shows best the even bedding of the whole. Fossils abundant throughout. At the base is the porous weathered siliceous limestone | 10 | 0 |
| 7. Very persistent clay-parting... ... ... ... ... ... | 3 | 0 |
| 8. Alternations of pure and clayey limestone, with a 6-inch clay parting about the middle ... ... ... ... ... ... | 12 | 0 |
| Total of Great Oolite limestone ... ... | 42 | 8 |

Below this come the Estuarine clays, but these are only just touched in this part of the cuttings and their details belong to the next section of the work.

*Ardley Wood to the Tunnel.*

This section of the work commences on the north side of the road at Ardley Wood, and from this point to the tunnel no cuttings have yet been made, and the intimate structure of the ground is not known. There is a sharp descent at the commencement of this area, and in the face of this slope three small trial pits have been made; the first two pass through the base of the Great Oolite into the Estuarine beds; while the third is sunk in the latter alone. The base of the limestone is thus accurately fixed and the outcrop is clearly a natural one. The third pit passed through the following beds:—

| | Ft. | in. |
|---|---|---|
| 1. Soil and clay ... ... ... ... | 4 | 0 |
| 2. Loamy sand, very fossiliferous ... ... | 5 | 0 |
| 3. Blue clay crowded very *Ostrea*... ... | 6 | 0 |
| 4 Grey sandstone with rootlets ... ... | 5 | 0 |

The tip-heap having become decomposed during the winter the fossils have been set free and thousands of specimens of a little *Ostrea* lie loose on the surface; they are accompanied by a great number of curiously distorted *Rhynchonellæ*. The assemblage of fossils is identical with that in a doubtful limestone seen later on, and is thus important. At the foot of the hill a pond was made in solid limestone; it has been puddled with Estuarine clay and when first seen was taken to be in Estuarine beds; Mr. Sikes fortunately explained the real nature of the rock taken out. At present this limestone is taken for the Great Oolite, as the "Cream-cheese' top of this rock is seen further on; thus, in any case, there is a second complete outcrop of the great limestone, either let down by a fault, or brought down by a sharp roll. Till the cuttings are made these points can not be settled. Some distance further on is a series of pits, mostly excavated in loose white and dark sand; but at the top of all is a curious rubbly red limestone, containing exactly the same assemblage of fossils as the Estuarine beds described above. The true relation of this to the beds already described is not known, but a bore close to the pits gives its exact position above the top of the Upper Lias as may be seen from the subjoined section.

*Boring close to the pits South of the Tunnel.*

| | Ft. | in. |
|---|---|---|
| 1. Soil and rock (the red limestone) ... | 5 | 0 |
| 2. White sand... ... ... ... ... | 7 | 6 |
| 3. Dark sand, traces of ironstone ... ... | 11 | 6 |
| 4. Wet sand ... ... ... ... ... | 13 | 0 |
| 5. Sandstone ... ... ... ... ... | 3 | 0 |
| 6. Sand... ... ... ... ... ... | 1 | 6 |
| 7. Sandstone ... ... ... ... ... | 2 | 0 |
| Upper Lias Clay below. | | |

The base of this curious red rubbly limestone is thus seen to be 38 ft. 6 ins. above the top of the Lias. The same bed of limestone appears to form a skin over the other beds right to the crest of the hill in which 4 shafts have been sunk; in the first of these the red limestone is about 44 ft. above the Lias, in the second 43 ft. In the third it can not be identified from the details of the section given; but in the fourth it is 44 ft. 6 in. above the Lias. The figures are sufficiently close to leave little doubt that this is one bed of limestone, but its relations to the Estuarine Series are not clear. The sands in the pits are clearly due to dissolution of the carbonate of lime in a calcareous sandstone, for cores have now been found both in the white sand and the black sand. The undecomposed rock is intensely hard; and a curious point in these sands is the variability of the horizon at which complete decalcification takes place, as the tunnel shafts given later, will show.

A visit was made to the tunnel to fix on a bed that can be recognised in the open, and sufficiently far above the top of the Lias to be exposed in the cutting yet to be made at the south-

eastern mouth of the tunnel. This has been accomplished; there is a markedly shelly band, a foot thick, with a clay matrix, about 11 ft. 8 ins. above the Lias; this clay band will be at once recognised in the cutting and give a datum line for reckoning when the latter is made. The sandy beds both above and below this band were quite decalcified in the tunnel.

The account of this part of the work may be concluded with the sections proved in the shafts to the tunnel.

### 3.—*Sections of Shafts to the Frutwell Tunnel.*

Communicated by Mr. Sikes.

| | | Ft. | in. |
|---|---|---|---|
| | **No. 1 Shaft.—O.D. 415 ft.** | | |
| | 1. Soil | 1 | 0 |
| | 2. Rubble of red limestone | 1 | 0 |
| Estuarine Beds | 3. Yellowish clay | 3 | 6 |
| Estuarine Beds | 4. Dirty black sand | 9 | 0 |
| Northampton Beds | 5. White sand | 13 | 6 |
| Northampton Beds | 6. Grey hard rock | 18 | 6 |
| | 7. In blue clay, Upper Lias | 18 | 0 |
| | **No. 2 Shaft.—O.D. 428 ft.** | | |
| | 1. Soil | 0 | 6 |
| | 2. Rubble (red limestone) | 5 | 1 |
| Estuarine Beds | 3. Yellow clay | 1 | 0 |
| Estuarine Beds | 4. Hard rock post | 1 | 0 |
| Estuarine Beds | 5. Clay | 0 | 6 |
| Estuarine Beds | 6. Hard rock | 1 | 3 |
| Estuarine Beds | 7. Clay, yellowish | 3 | 9 |
| Northampton Beds | 8. Sand | 27 | 0 |
| Northampton Beds | 9. Rock | 9 | 0 |
| | 10. In blue clay, Upper Lias | 32 | 0 |
| | **No. 3 Shaft.—O.D. 449 ft.** | | |
| | 1. Soil | 1 | 0 |
| Estuarine Beds | 2. Yellow clay | 8 | 8 |
| Estuarine Beds | 3. Mixed rock and clay (disturbed) | 23 | 0 |
| Northampton Beds | 4. Sand | 25 | 0 |
| Northampton Beds | 5. Hard rock | 7 | 0 |
| | 6. In blue clay, Upper Lias | 42 | 0 |
| | **No. 4 Shaft.—O.D. 440 ft.** | | |
| | 1. Soil | 1 | 0 |
| | 2. Clay | 1 | 6 |
| | 3. Rubble | 2 | 0 |
| | 4. Solid bed of rock | 1 | 6 |
| Estuarine Beds | 5. Clay | 1 | 0 |
| Estuarine Beds | 6. Rock and clay | 20 | 0 |
| Northampton Beds | 7. Rock | 2 | 6 |
| Northampton Beds | 8. Sand | 19 | 0 |
| Northampton Beds | 9. Rock | 2 | 0 |
| | 10. In blue clay, Upper Lias | 51 | 0 |

The hard rock immediately above the Lias crops out above the mouth of the tunnel; the basal band is a flaggy and sandy limestone with small fossils; it weathers yellowish brown with grey cores; above is a yellowish harder and more solid sandy limestone; the latter is oolitic in part and contains pebbles and fossils in patches; in many respects it closely resembles the Dogger at the base of the Oolites in East Yorkshire.

*The Tunnel to Aynho Station.*

A considerable portion of the Upper Lias was exposed in the tunnel mouth and in the great tip-heap outside. It is here a silt composed of alternating laminæ of very fine grey mud and soft fine brown more sandy material. The whole of the first 50 ft. is almost destitute of fossils, but the exact cause is not easily explained. Possibly the conditions under which such rocks are accumulated favour the dissolution of at least thinner shells, for similar deposits in other regions show a similar paucity of organic remains.

From the tunnel mouth to some distance beyond Aynho Station the line will run on an embankment broken only by viaducts and bridges. For information on this section of the line we are entirely indebted to Mr. Sikes.

Not far from the tunnel mouth the hill-slope flattens owing to the presence of a harder bed. A deep drain proves this to belong to the basement limestones of the Upper Lias, as fragments of specimens of *Ammonites bifrons* and *A. annulatus* can still be found in the spoil heap. A little further on in the same drain the ferruginous bed at the top of the Middle Lias was cut open; nests of *Rhynchonella tetrahedra* are common here, while the curious flattened ferruginous concretions, that so closely resemble pebbles, are abundant. It may be here noted that whatever origin be ascribed to these bodies they are abundant in this rock over the whole area and are never absent from it.

A little beyond this point a viaduct crosses a small stream, and the piers of it gave some interesting evidence. The first penetrated the impure ironstone again, and here some blocks contained *Ammonites spinatus*, while all contain the concretions. The rock is a kind of bastard shelly limestone, locally altered to ironstone; in fact resembling the type of ironstone so often met with at this horizon in Oxfordshire and many parts of Great Britain, notably in north-east Yorkshire (the Cleveland Ironstone). Before reaching the little stream one of the piers was sunk in the sandy beds of the Middle Lias, often known in Yorkshire as the *Cardium truncatum* sandstones, and characterised by *Ammonites margaritatus*. An Ammonite, at least allied to this, occurs in one of the specimens preserved. Beyond the bridge there must be either a fault, or a sharp roll over in the dip, for the basement part of the Upper Lias was met with, containing abundant fossils; *A. bifrons* and *A. annulatus* are specially common. The latter is locally found in the rock-bed and in the "Transition bed" between the Middle and Upper Lias, where *A. acutus* is characteristic.

For some distance there is a blank in the evidence, but the foundations of a bridge over Wharf Lane were sunk through the base of the Ironstone, with the characteristic nodules, into the shales below. This is an important piece of evidence as it necessitates a change in the published map.

Before reaching Aynho another viaduct crosses some old fish-ponds, and in the foundations Ammonites of the Capricornus type are common and show that Lower Lias clays have been reached. At the viaduct it is clear that the hard bands at the junction of the Middle and Upper Lias form a kind of semicircle around the hollow in which these soft dark clays with *A. capricornus* occur. The northern end of the semicircle is not reached till Aynho Station is passed; and there are no sections in the intervening ground. The outcrop of the Ironstone occurs a little to the south of the bridge near Nellbridge Farm. It is repeated at the bridge itself owing to the occurrence of a small local syncline between the two outcrops. Half way between, apparently quite at the top of the bed, a specially large specimen of *Pecten æquivalvis* was found by Mr. Sikes, and this he has kindly presented to the Museum at Jermyn St. A very large amount of the ironstone was also cut open on the eastern approach to the main line of the Great Western Railway, and the rock is specially rich in fossils, though the number of species does not seem large. The most abundant are *Rhynchonella tetrahedra* and *Terebratula punctata*, in specially good preservation. The ubiquitous ironstone concretions abound, but *A. spinatus* is very rare here.

## *Drift.*

No true Boulder-clay or Glacial sand has been met with along the entire route; but with the possible exception of the ground in the south-eastern part of the area traversed, pebbles derived from the drifts are scattered plentifully over the entire district. The turf has almost everywhere been cut off, exposing the bare soil and on this the pebbles occur. They are more abundant in some spots than others, but occur in apparently no relation to the form of the ground; sometimes they are more common at the crest of a small rise than at the bottom of the adjacent hollow; at other times the reverse is the case. Practically all the pebbles observed were either quartzite, derived from the Bunter originally, or formed of vein quartz. No fragments of rock that could not have come originally from some part of the Midlands were noted; but no special search was made for them; one can only say with confidence, if there are any at all, they are exceedingly rare. Such scatterings of Bunter quartzite pebbles are not uncommon in Midland areas near the former limits of the ice that brought the Boulder Clay, and they occur also in areas that have been subject to much erosion subsequent to and following the period of maximum glaciation.

## V.—The New Great Western Branch Railway from Camerton to Limpley Stoke, Somerset.

By Horace B. Woodward, F.R.S.

The new railway extends along the valley of the Cam Brook, and follows over great part of its course the Somerset Coal Canal, the construction of which was planned and superintended by William Smith, during the years 1794-99; in part from Bath, in part from his residence at Tucking Mill, Midford (1798-99).*

At Camerton Station the railway has been excavated through a portion of the coal-tip of the Camerton Colliery. A little further on it crosses the Cam Brook, and on the south side, where a fresh course has been cut for the stream, there were exposed 10 ft. of red clayey sands and sandy clays with hard bands of calcareous red sandstone, some with coarse detrital grains which give to portions of the rock a finely conglomeratic appearance, approaching in character to varieties of the Dolomitic Conglomerate. The rock contained drusy patches of calcite with a small quantity of baryto-celestite, determined by Dr. W. Pollard.

These sandy beds, which appear also in cuttings along the older portion of this branch railway near Hallatrow, were included with the Keuper Marls on the old one-inch geological map. Similar strata were excavated in a new cut for the stream north of the Old Malthouse, Wicklane.

The Alluvium in this area is seen to consist largely of red sandy clay derived from the New Red Strata, and this feature is noticeable far down the Cam Valley, where the new railway crosses the stream to the south-west of Midford Station.

Beyond Wicklane and west of Carlingcott Mill, there were shallow cuttings in red and green sandy clays with hard red and pale green or white calcareous bands, belonging to higher portions of the Keuper. East of the bridge over the railway, N.E. of Carlingcott Mill and west of Stoneage Farm, the Rhætic Beds appear for a short distance; but they were imperfectly exposed, as the strata along the steep slopes here and elsewhere are much affected by land-slipping.

Traces of White Lias occurred in the upper slopes, above the following beds:—

| | | Ft. | In. |
|---|---|---|---|
| *Avicula-contorta* Beds | Black shales seen to a depth of ... ... ... | 4 | 0 |
| | Thin sandy and pyritic layer ... ... ... | 0 | 1 |
| Grey Marls. | Greenish marly clay ... ... ... ... | 0 | 10 |
| | Brown clay ... ... ... ... ... ... | 0 | 10 |
| | Hard beds of greenish grey and bluish marly and sandy rock, 2 layers ... ... ... | 3 | 0 |
| | Bluish green clay seen to a depth of ... ... | 2 | 0 |

The Grey Marls are probably not more than 12 ft. thick. The thickness is less in some parts of the Radstock district.†

* See "Memoirs of William Smith," by John Phillips, 1844, p. 14.

† See "Geology of East Somerset and the Bristol Coal fields," *Mem. Geol. Surv.*, 1876, p. 77.

The Rhætic Beds end abruptly about 150 yds. east of the railway-bridge where they are faulted against hard limestones of the Lower Lias. These latter beds, which are not interbedded with clays, were noted as follows:—

| | Ft. |
|---|---|
| Brown clay ... ... ... ... ... ... ... ... | 10 |
| Hard brown limestones with phosphatic nodules and pebbles in upper part; also *Ammonites, Gryphæa arcuata, Spiriferina Walcotti, Rhynchonella, Terebratula*; in lower part *Lima succincta, Pecten calvus, Rhynchonella*... ... ... ... | 15 |

*Spiriferina Walcotti* is found also in the clays overlying the limestones in this neighbourhood.*

The following species from the upper beds of the limestone were identified by Dr. Ivor Thomas: *Microthyris perforata* (Piette), *Rhynchonella variabilis* (Schloth.), *Unicardium cardioides* (Phill.), and *Coroniceras sauzeanum* (d'Orb.)

Further to the east the cuttings are continued in blue clay, and at a higher level, in a line between Splot Farm and Hill Grove House, there were slipped masses of ferruginous iron-shot limestone and pale limestone blocks about 4 ft. thick, the lower portion containing traces of lignite, many *Belemnites, Rhynchonella*, etc., and the upper part yielding *Ammonites communis*?

This rock-band represents the Marlstone and basement Upper Lias. Occurring on the hill slope where slipping had taken place, it was only approximately *in situ*, although not far removed from position.

The fact that the Marlstone and associated Upper Lias rock occur as a thin band in the midst of blue clays that are seldom exposed, accounts for the difficulty that has been experienced in tracing the boundaries of Lower, Middle and Upper Lias in the neighbourhood of Bath.† There appears to be no local development of Middle Lias sandy beds along the Cam Valley.

The general inclination of the strata is to the north-east. Further on there were more blue clays with a band of cement-stones well exposed in the cuttings where the footpath from Splot Farm to Hill Grove House crosses the railway. Here again, in the higher part of the cutting, there were slipped masses of limestone, but in this case they were beds of somewhat cavernous oolite, of Inferior Oolite age, with *Terebratula globata, Trigonia*, &c.

No trace of Midford Sands was here discernible. In the cutting by the loop of the canal N.W. of Dunkerton Church, about 10 ft. of Inferior Oolite (Trigonia beds), with large *Gervillia*, was seen above 5 ft. of mealy sandstone and sandy clays or clayey sands belonging to the Midford Sands.

The cutting near the Rectory, to the east, was excavated in hard lime-washed Oolite with *Trigonia*. North-east of the

* See "Jurassic Rocks of Britain," *Mem. Geol. Surv.*, vol. iii., p. 132.
† "Jurassic Rocks of Britain," vol. iii., p. 126.

Swan Inn, Dunkerton,* the junction of Inferior Oolite, somewhat tumbled, with underlying grey sand (Midford Sand) was exposed. For some distance the railway continues near this junction, but mainly on rubbly oolite. North of Combe Hay, and west of Rowley Farm, the ground is formed of slipped Fuller's Earth Clay and rubbly Oolite.

A good section of Inferior Oolite has been exposed in the first cutting east of the Anchor Inn, Combe Hay. There the Coral beds and Trigonia Grit were shown above 4 ft. of grey sand with indurated band (Midford Sand).

The best section of these strata was that opened up about ½ mile west of the Midford Viaduct. It showed the sequence in the district described many years ago by William Lonsdale,† and worked out in great detail last year in the road-cutting at Midford, by Mr. Linsdall Richardson.‡

The main features of the railway-section which were noted in company with the Rev. H. H. Winwood, are as follows;—

| | | Ft. |
|---|---|---|
| Inferior Oolite | Pale oolite, rubbly—a few feet. | |
| | Hard beds of oolitic freestone, for the most part fine grained, but much shattered and lime-washed. *Trigonia, Terebratula globata, Serpula.* Portions of the rock have small cavities due to the dissolution of shells. Bored-beds occur here and there. The beds rest evenly on those below ... ... | 13 |
| | Coral-beds. The highest portion oolitic limestone with *Trigonia* and corals. The mass composed largely of blocks of coral-limestone with some well preserved corals (*Isastrea*). The whole much brecciated and broken, probably by dissolution... | 13 |
| | Hard iron-shot limestones, slightly cavernous owing to dissolution of shells. *Ammonites, Belemnites, Trigonia, Trichites, Pecten.* Small pebbles, and derived fragments of calcareous sandstone from the Midford Sands occur at or near the base. The beds rest irregularly on a bored surface of those below ... ... ... ... ... ... ... | 9 |
| Midford Sands | Grey sands with indurated bands, the top layer a hard sandstone. Seen to a depth of about ... | 7 |

Excavations in Midford Sands, grey sands with indurated bands, were made for the foundations of the bridge on the eastern side of Cam Brook. Further on there is a cutting in Midford Sands with 2 or 3 ft. of rubble (downwash) of Inferior Oolite on top.

North of Bridge Farm, Midford, there are cuttings in Midford Sands, with indications of Lias Clay by the western fence of the railway, about 200 yds. north of the high road. Rubble of Inferior Oolite occurs above the sands by Slittems Wood. Beyond this, the railway follows the Midford Brook to join the Bathampton Branch Railway north of Limpley Stoke, and no cuttings at the time of my visit had been made.

* Observations recorded by Wm. Smith at this Inn, were printed in the "Memoirs" by John Phillips, already cited, pp. 17, 20.

† *Trans. Geol. Soc.*, sec. 2, vol. iii., p. 248.

‡ *Quart. Journ. Geol. Soc.*, vol. lxiii., p. 406.

## VI.—Notes on the Indexes of Colours issued by the Geological Survey of Great Britain, and on the dates of the Earlier Published Maps of Cornwall, Devon, and West Somerset.

By Horace B. Woodward, F.R.S.

Owing to the fact that no dates were affixed to the earlier published maps of the Geological Survey, there has been difficulty in determining when the several sheets, and when revised editions of certain of them, were first issued.

Some information has, however, been gathered from a study of the successive Indexes of Colours, and from the references to the progress of the Geological Survey that were printed in the Proceedings of the Geological Society.*

Mention will first be made of the original MS. Index of Colours approved by the Council of that Society, and particulars will then be given of the geological formations represented on the first three published indexes, and also of the colours therein adopted by the Geological Survey. The tints have been identified, as nearly as possible, by Mr. H. W. Gilbert Williams, and the record will therefore be useful in identifying particular editions of the maps.

### 1*st MS. Index of Colours.*

R. I. Murchison, in his Address to the Geological Society, on the 15th February, 1833, stated that:—

"The adoption of a fixed scale of colours by all English geologists is still an essential desideratum in this department; and I am happy to have it in my power to state, that a systematic arrangement will shortly be submitted to you, after it has undergone the supervision of our Council, and shall have met with the general approval of the Board of Ordnance. This scale, being founded on the principle of employing such colours only as are fixed and distinct from each other, has been suggested by our valued member, Mr. [afterwards Sir Francis] Chantrey."†

Preserved in the Library of the Geological Survey and Museum, at Jermyn Street, is the following MS. entitled:

"Colours to be employed in colouring geologically Sheets 21, 22, 23, 24, 25, 26 and 27 of the Ordnance Map of Great Britain.

"These colours are copied from those deposited in this Office by H. T. De la Beche, Esq., after they had received the sanction of the Council of the Geological Society of London on the 16th May, 1832. They are the same as those at present adopted by G. B. Greenough, Esq., for the 2nd edition of his Geological Map of England and Wales, preparing for publication.

"A. W. Robe, Capt. R.E.
"22nd June, 1832.
"Ordnance Map Office, Tower."

"To R. I. Murchison, Esq., P.G.S., etc., etc."

* See also "History of the Geological Society of London," 1907, pp. 100—113.
† *Proc. Geol. Soc.*, vol. i., p. 447.

## 1st *Published Index of Colours*, 1834; *and Maps* 1834 *and* 1835.

G. B. Greenough announced in his Address to the Geological Society, 21st February, 1834, that:

"Mr. De la Beche, one of our Vice-Presidents, acting under the direction of the Board of Ordnance, has produced a geological map of the County of Devon, which, for extent and minuteness of information and beauty of execution, has a very high claim to regard."*

On the 20th February, 1835, Greenough stated:

"The researches of your Vice-President in the counties of Devon and Somerset have been carried on this year with increased energy. Of the eight sheets of the Ordnance Map upon which he has been engaged, four were published last spring, three others are complete, the eighth is nearly complete."†

The maps included in the County of *Devon* were Sheets 20, 21, 22, 23, 24, 25, 26 and 27. With them was issued as a separate sheet, an Index of Colours and Explanation of Signs, with an engraved title as follows: "Ordnance Geological Map of Devon, with parts of Cornwall and Somerset, by Henry T. De la Beche, F.R.S., V.P.G.S., etc.," (sold by J. Gardner, agent for the sale of Ordnance Surveys, 163, Regent Street, London).

This title-sheet with index is affixed to the copy of Sheet 23 preserved in the Museum of Practical Geology, and there can be no doubt that this map was one of the four issued in the spring of 1834. It is probable that the three other sheets were 20 (excluding the part of Glamorganshire), 21 and 22. It will be observed in the statement of the 20th Feb., 1835, that the county of Somerset is specially mentioned; if Sheet 24 had then been published it is likely that Cornwall would have been mentioned. The presumption, therefore, is that Sheets 24, 25, 26 and 27 were published at a later period, in 1835.

The formations represented on this first published "Index of Colours, 1834, were as follows:—

| | |
|---|---|
| Alluvial ... ... ... ... ... ... | *Pale blue streaks.* |
| Bovey coal deposit ... ... ... ... | *Pale brown with brown dots.* |
| Chalk ... ... ... ... ... ... | *Pale creamy white.* |
| Green Sand ... ... ... ... ... | *Emerald green.* |
| Inferior Oolite ... ... ... ... ... | *Pale chrome.* |
| Lias ... ... ... ... ... ... | *Chalons brown.* |
| New Red Sandstone ... ... ... ... | *Venetian red pale.* |
| Magnesian Limestone... ... ... ... | *The same, dark.* |
| Grauwacke ... ... ... ... ... | *Pale blue-grey.* |
| Grauwacke Limestone ... ... ... | *Cobalt.* |
| Grauwacke Dolomite ... ... ... ... | *The same with carmine lines.* |
| Altered Grauwacke ... ... ... ... | *Pale blue-grey with green dots.* |
| Quartz Rock ... ... ... ... ... | *Chrome with streaks of carmine.* |
| Greenstone and common Trappean Rocks... | *Sap green.* |
| Hypersthene Rock ... ... ... ... | *The same pale, with carmine dots.* |
| Serpentine ... ... ... ... ... | *The same pale, with carmine lines.* |

* *Proc. Geol. Soc.*, vol. ii., p. 51.
† *Ibid.*, vol. ii., p. 154.

| | |
|---|---|
| Felspar Porphyry ... ... ... | ... *Crimson lake with blue dots.* |
| Granite ... ... ... ... ... | ... *Crimson lake.* |
| Hornblende Rock and Chlorite Slate | ... *Greenish-grey.* |
| Mica Slate and Gneiss ... ... | ... *Pale brown with carmine dots.* |

## *2nd Published Index of Colours*, 1839.

De la Beche's Map of *Devon, with parts of Cornwall and Somerset,* was revised before the publication of the entire series that accompanied his Report on the Geology of Cornwall, Devon and West Somerset.

These maps—Sheets 20 to 27 were revised, while Sheets 28, 29, 30, 31, 32 and 33 were first issued in 1839.

The revisions in the earlier maps were mainly, if not entirely, in the separation of the Carbonaceous Series from the Grauwacke Series.*

The above maps were accompanied by a separate sheet entitled: "Colours and Signs employed in the Ordnance Geological Maps of Cornwall, Devon, and West Somerset."

This second index of colours and signs contained the following tablets:—

| | |
|---|---|
| Blown Sands ... ... ... ... | ... *Burnt umber dots.* |
| Alluvial ... ... ... ... ... | ... *Greenish-grey.* |
| St. Agnes Clay, Sands, &c. ... ... | ... *Yellowish-brown with black dots.* |
| Bovey Clay, Lignite, &c. ... ... | ... *Pale brown with deeper stripes.* |
| Chalk ... ... ... ... ... | ... *Creamy white.* |
| Green Sand ... ... ... ... | ... *Emerald green.* |
| Inferior Oolite ... ... ... ... | ... *Pale brownish yellow.* |
| Lias ... ... ... ... ... | ... *Sepia.* |
| Red Sandstone Series... ... ... | ... *Pale Venetian red.* |
| Magnesian Conglomerates and Limestones associated with the Red Sandstone Series | *Chalons brown and Venetian red.* |
| Carboniferous Limestone ... ... | ... *Pale Prussian blue.* |
| Carbonaceous Series of Devon and Cornwall | *Deep neutral tint.* |
| Beds of Anthracite in the same Series | ... *Bistre.* |
| Limestone in the same Series ... | ... *Indigo.* |
| Grauwacke Series ... ... ... | ... *Pale neutral tint.* |
| Limestone in the same Series ... | ... *Cobalt.* |
| Quartz Rock in the same Series ... | ... *Mars yellow with zig-zag carmine lines.* |
| Quartzo-felspathic Rock of St. Columb, Withiel, &c. | *Rubens' madder with blue stripes.* |
| Hornblende Rock and Slate ... ... | ... *Sap green with carmine dots.* |
| Chlorite Rock and Slate, Mica Slate and Gneiss | *Violet carmine.* |
| Igneous Rocks associated with the Red Sandstone Series | *Deep Venetian red.* |
| Elvan, or Granitic and Felspar Porphyry Dykes | *Deep crimson lake.* |
| Granite, including Schorl Rock ... | ... *Pale crimson lake.* |
| Trappean Ash and Hard Trappean Rock, associated with the Carbonaceous Rocks and Grauwacke Series | *Grey green.* |
| Diallage Rock ... ... ... ... | ... *Vandyke brown.* |
| Serpentine ... ... ... ... | ... *Yellow ochre.* |

* See Address to Geological Society, February 21st, 1840, by Wm. Buckland, *Proc. Geol. Soc.*, vol. iii., pp. 221 and 227.

### *3rd Published Index of Colours, date probably* 1844.

The Third Index was entitled: "Index to the Colours and Signs employed in the Geological Survey of Great Britain for South Western England and South Wales." It was issued probably in 1844. In 1846 this Index was reproduced in a smaller form, both tablets and writing being on a reduced scale. The title was headed (Ordnance Survey), and a legend at the foot indicated its issue thus: "London, Pubd. 24th August, 1846, by J. Arrowsmith, 10 Soho Square."

On this smaller form there was engraved a statement of the "Price of the different Sheets of the Ordnance Survey, Geologically Coloured according to Sir Henry de la Beche; Director General of the Ordnance Survey" (*sic*). The Sheets then published were Nos. 19 to 43, excluding Sheet 34.* Evidently this smaller Index Sheet was issued by the map agent, and was not an official publication.

The tablets and legends were otherwise identical on the two Index Sheets, and the French and German names of the formations or rocks were inserted.

The Index was fuller than was needed at the time, but it was evidently drawn up to include the formations represented in Wiltshire and Dorsetshire. No Index-tablets appear to have been engraved on the maps themselves prior to about the year 1850.

The tablets shown on this third Index were as follows:—

| | |
|---|---|
| Blown Sand ... ... ... ... ... | *Burnt ochre dots.* |
| Alluvium ... ... ... ... ... | *Greenish-grey.* |
| Shelly beds of more recently raised Sea or Estuary bottoms (Burtle Beds) | *Burnt ochre in zig-zag bands.* |
| Gravel, &c. More ancient drift, when so concealing subjacent rocks as to leave them uncertain | *Carmine dots between oblique wavy lemon-yellow lines.* |
| Bovey Lignite and Clay ... ... ... | *Burnt ochre and stripes of same.* |
| Plastic Clay ... ... ... ... ... | *Burnt ochre with French blue dots.* |
| Upper Chalk ... ... ... ... | *Very pale warm sepia.* |
| Lower Chalk ... ... ... ... | |
| Upper Greensand ... ... ... ... | *Emerald green (mixed).* |
| Galt ... ... ... ... ... | *Prussian green.* |
| Lower Greensand ... ... ... ... | *Emerald green (mixed) with carmine dots.* |
| Purbeck Beds ... ... ... ... ... | *Pale orange with carmine dots.* |
| Portland Oolite ... ... ... ... | *Roman ochre.* |
| Portland Sands ... ... ... ... | *The same, with carmine dots.* |
| Kimmeridge Clay ... ... ... ... | *Pale blue black.* |
| Coral Rag. Oxford Oolite ... ... ... | *Deep orange chrome.* |
| Oxford Clay ... ... ... ... ... | *Light red.* |
| Cornbrash ... ... ... ... ... | *Mars yellow.* |
| Forest Marble ... ... ... ... ... | *Yellow ochre.* |
| Great or Bath Oolite ... ... ... ... | *Lemon yellow.* |
| Fuller's Earth ... ... ... ... ... | *Warm sepia.* |
| Fuller's Earth Rock ... ... ... ... | *Purple brown.* |
| Inferior Oolite ... ... ... ... ... | *Lemon yellow, darker.* |
| Inferior Oolite Sands ... ... ... ... | *The same, with carmine dots.* |

* In 1846 the Geological Survey maps in the Library of the Geological Society included Sheets 19 to 33 and 35 to 43.

| | |
|---|---|
| Upper Lias ... ... ... ... ... | *Dark warm sepia.* |
| Marlstone ... ... ... ... ... | *Yellowish brown.* |
| Lower Lias ... ... ... ... ... | *Same as Upper Lias.* |
| Red and Variegated Marls ... ... ... | *Venetian red.* |
| Grey Sandstones and Shales in the Red Marls | *Venetian red and indigo.* |
| Red Sandstone... ... ... ... | *Venetian red with wavy stripes of deeper tint of the same.* |
| Red Conglomerate ... ... ... | |
| Magnesian Limestone and Conglomerate. (In this district these rocks occur in all parts of the Series) | *Deep Venetian red.* |
| Coal Measures... ... ... ... ... | *Sepia.* |
| Millstone Grit ... ... ... ... ... | *Gamboge over Sepia.* |
| Limestone in Coal Measures or Millstone Grit | *Indigo deep.* |
| Carboniferous Limestone ... ... ... | *Prussian blue.* |
| Lower Carboniferous Limestone Shale ... | *The same dark.* |
| Old Red Sandstone ... ... ... ... | *Indian red.* |
| Limestone named Cornstone in the Old Red Sandstone | *Prussian blue over Indian red.* |
| Devonian Rocks. (A provisional colour, as there is reason to consider that the rocks included under this head in Cornwall and Devon are equivalents of Carboniferous Limestone, Old Red Sandstone, and Upper Silurian Rocks) | *Pinkish neutral.* |
| Upper Silurian Rocks ... ... ... | *Violet.* |
| Lower Silurian Rocks and Cambrian Rocks | *Violet, paler.* |
| Limestone in the Devonian and Silurian Rocks | *Cobalt.* |
| Hornblende Slate and Rock... ... ... | *Hooker's green with wavy network of carmine.* |
| Chlorite Slate, Mica Slate, and Gneiss ... | *Violet carmine.* |
| Syenite, Greenstone, and common Trappean rocks, containing Hornblende. Trappean Ash | *Hooker's green.* |
| Felspathic Rocks in which Hornblende rarely occurs, associated with Ordinary Trappean Rocks | *The same, with wavy lines of carmine.* |
| Hypersthene Rock ... ... ... ... | *Hooker's green with carmine dots.* |
| Trappean Rocks associated with the New Red Sandstone Series of Devonshire | *Orange vermillion with wavy lines of carmine.* |
| Diallage Rock ... ... ... ... ... | *Pale Hooker's green with lines of same in deeper tint.* |
| Serpentine ... ... ... ... ... | *Sap green.* |
| Felspar Porphyry, Elvan ... ... ... | *Carmine deep.* |
| Granite ... ... ... ... ... ... | *Crimson lake.* |

Some changes in colour and MS. additions were made after 1846 and before 1856 in a copy of this Index preserved in the Library at Jermyn Street. The alterations are as follows:

| | |
|---|---|
| Gravel, &c. ... ... ... ... ... | *Wavy lines of orange yellow.* |
| Bovey Lignite and Clay ... ... ... | *Paler burnt ochre with wavy lines of burnt ochre.* |
| Plastic Clay ... ... ... ... ... | *Neutral tint.* |
| Hastings Sand ... ... ... ... ... | *Tint as before, without dots.* |
| Purbeck Beds ... ... ... ... ... | *Pale purple.* |
| Fuller's Earth Rock ... ... ... ... | *Burnt carmine.* |
| Inferior Oolite... ... ... ... ... | *Orange yellow.* |
| Inferior Oolite Sands... ... ... ... | *Orange yellow ground.* |
| Upper Lias ... ... ... ... ... | *Pale warm sepia.* |
| Marlstone ... ... ... ... ... | *Brown orange.* |

| | |
|---|---|
| Lower Lias ... ... ... ... | ... *Pale warm sepia.* |
| Red Sandstone... ... ... ... | ... *Tint as before without wavy lines.* |
| Red Conglomerate ... ... ... | ... *Pinkish grey ground without wavy lines.* |
| Cornstone ... ... ... ... | ... *Very deep Payne's grey.* |
| Permian... ... ... ... ... | ... *Greyish madder brown.* |
| Ludlow Rocks ... ... ... ... | ... *Payne's grey.* |
| Wenlock Shale... ... ... ... | ... *Rather deep purple.* |
| Caradoc Sandstone ... ... ... | ... *Pale warm green.* |
| Lower Silurian... ... ... ... | ... *Pale purple.* |
| Cambrian ... ... ... ... | ... *Pale purple brown.* |
| Hornblende Slate ... ... ... | ... *Pale Hooker's green without wavy lines.* |
| Chlorite Slate, etc. ... ... ... | ... *Pale madder lake.* |
| Syenite ... ... ... ... ... | ... *Deep orange crimson.* |
| Felspathic Rocks ... ... ... | ... *Pale Mars red.* |
| Hypersthene Rock ... ... ... | ... *Pale Hooker's green with carmine dots.* |
| Diallage Rock ... ... ... | ... *Pale sage green.* |
| Serpentine ... ... ... ... | ... *Pale bright yellow-green.* |
| Felspar Porphyry ... ... ... | ... *Deep carmine.* |
| Granite... ... ... ... ... | ... *Medium carmine.* |

It was during the period when the above changes were introduced that Index Tablets (without Index Letters) were introduced in the Maps.

### *4th Published Index of Colours*, 1856.

The "Index to the Colours and Signs employed in the Geological Survey of Great Britain for Wales, the Midland, Southern and Western Counties of England," was issued in January, 1856, Sir R. I. Murchison, Director General. Letters were now for the first time used on the tablets and maps to indicate the formations; and it may be noted that the tablets for metamorphic rocks were increased, and κ was used for the Altered Devonian of South Devon.

### *Later Published Indexes of Colours*, 1865—1874.

5th published Index to the Colours and Signs employed in the maps and sections of the Geological Survey of Great Britain up to 1865.

This was greatly revised, especially as regards Tablets for Old Red Sandstone, Permian, Carboniferous, Wealden and Eocene.

6th revised up to 1867—a few verbal alterations.

7th revised up to 1869—Silurian and Carboniferous tables revised.

8th revised up to 1871—(date 1871 under title, 1869 at foot) Jurassic sub-divisions revised.

9th revised up to 1874—Igneous, Recent and Tertiary tablets revised.

## VII.—List of Maps and Sections, with MS. Geological Information, of Parts of Great Britain, in the Library of the Geological Survey and Museum. 1908.

By C. V. Crook, B.A.

In addition to the maps in this list there are official six-inch MS. geological maps of parts of the following counties and islands:—

### *England and Wales.*

Bedford.
Berkshire.
*Brecknock.
Buckingham.
Cambridge.
*Carmarthen.
Cheshire.
Cornwall.
*Cumberland.
Denbigh.
*Derby.
Devon.
Dorset.
*Durham (complete).
Essex.
Flint.
*Glamorgan.
Gloucester.
Hampshire (nearly complete) and Isle of Wight (complete).
Hertford.
Huntingdon.
Kent.
*Lancashire.
*Leicester.
Lincoln.
Merioneth.
Middlesex and London.
*Monmouth.
Northampton.
*Northumberland.
Nottingham.
Oxford.
Rutland.
Shropshire.
Somerset.
*Stafford.
Surrey.
Sussex.
Warwick.
Westmorland.
Wiltshire.
Worcester.
*York.
Isle of Man (complete).

### *Scotland.*

Deposited in Geological Survey Office, Edinburgh.

Aberdeen.
Argyll.
*Ayr.
Banff.
Berwick.
Caithness.
*Clackmannan.
*Dumbarton.
*Dumfries.
*Edinburgh.
Elgin.
*Fife.
Forfar
Haddington (complete).
Roxburgh.
*Kinross.
Kirkcudbright.
*Lanark.
*Linlithgow.
Peebles (complete).
*Perth
*Renfrew.
Ross.
Roxburgh.
Selkirk.
*Stirling.
*Sutherland.
Wigton (complete).

* N.B.—Some of the 6-inch maps of coalfields and other areas in these counties are published.

BERKSHIRE. (See Middlesex).

BRECKNOCKSHIRE. (See Glamorganshire).

BUCKINGHAMSHIRE. (See Middlesex).

CAMBRIDGESHIRE.

Cambridge and neighbourhood.—One-inch, Old Series, Map, 51 S.W. (A. J. JUKES-BROWNE). 1872.

Cambridge.—F. S. Craig's Map. (A. J. JUKES-BROWNE) 1:7040. 1875.

CORNWALL. (See also Devonshire).

Gorran parish.—(C. W. PEACH). 1:25,000. n.d.

Cornwall.—T. Martyn's Map. Granite bosses shown in MS. 1:150,000 approx. 1784.

Cornwall, showing localities of fossils. (C. W. PEACH). 1:63,360. n.d.

CUMBERLAND.

Alston.—Great Sulphur Vein. Plan and section. (F. S. REID). n.d.

Alston Moor.—Plan of Sir John's Vein Sett. 1:2500 approx. n.d.

DERBYSHIRE.

Harpur Hill Quarries.—Plan and section. 1:2520. n.d.

Ashover to Sutton.—Horizontal Geological Section. (J. FAREY). 1808.

Wigley to Langwith.—Horizontal Geological Section. (J. FAREY). 1808.

DEVON.

Bideford and Barnstaple District.—Culm-measures. One-inch map, New Series, 292 and 293. (I. ROGERS). n.d.

Teignmouth and Totnes District.—One-inch map, Old Series, 22. (A. CHAMPERNOWNE). 1886.

Torquay.—(H. B. WOODWARD). 1:10,000 approx. 1874—75.

Devon, Cornwall, and Somerset.—One-inch maps, Old Series, 20, 21, 22, 23, 24, 26, 27. With geological information later than that of the published editions. (J. H. BLAKE, H. W. BRISTOW, W. A. E. USSHER, and H. B. WOODWARD). 1870—77.

South Devon Coast from Teignmouth to Lyme Regis.—Horizontal Geological Section for One-inch Map, Old Series, 22. (W. A. E. USSHER). 1880.

DORSET.

Portland.—Six-inch Ordnance Map 58 and 60, Geological in places. (SIR. J. PRESTWICH).

Dorset, South and part of Hampshire.—One-inch Maps, Old Series 15, 16, 17. Tertiary Geology. (J. TRIMMER). n.d. [between 1846 and 1854.]

ESSEX.—(See Middlesex).

GLAMORGANSHIRE.

Glamorganshire, Pembrokeshire and Brecknockshire.—One-inch Maps, Old Series, 36, 37, 42. Geological in part. (W. D. CONYBEARE and H. MCLAUCHLAN). n.d.

GLOUCESTERSHIRE.

Avon Gorge.—Horizontal Geological Section. n.d.

Cheltenham to Birmingham.—Section of the Birmingham and Gloucester Railway. Horizontal Section by W. S. Moorson. (Geology by H. E. STRICKLAND). 1840.

HAMPSHIRE. (See Dorset and Middlesex).

HERTFORDSHIRE. (See Middlesex).

KENT. (See also Middlesex).

Chislehurst.—Plan of Old Chalk Workings. 1:396. 1904.

Rye to Folkestone.—Coast Erosion. One-inch Map, Old Series, 4. (R. FIELD). 1891.

KENT. Six-inch Maps, Kent 28, 29, 30. Partly geological. (SIR J. PRESTWICH). n.d.

LANCASHIRE.

Liverpool. Six-inch Geological Maps, Lancs. 106, 113 N.W. and N.E. (G. H. MORTON). 1898.

Manchester Ship Canal.—Three Horizontal Geological Sections. 1892-3.

LEICESTERSHIRE.

Tilton and Medbourne.—New Railway. Geological Section shown in cutting. (E. WILSON). n.d.

LINCOLNSHIRE.

Grantham and Stamford.—Great Northern Railway between. Geological Map and Sections. (SIR J. PRESTWICH). 1851.

Wash.—Map showing the enclosures on the coast at various times. One-inch Map, Old Series, 69. n.d.

MERIONETHSHIRE.

Merionethshire Manganese District.—One-inch Maps, New Series, 135, 149; also Six-inch Maps 19 N.E., S.W., S.E., 26 N.W., S.W., S.E., 31 S.E., with 32 S.W., 32 N.E., 36 N.W. (J. G. GOODCHILD). 1888.

MIDDLESEX.

Middlesex and adjoining Counties.—One-inch Maps, Old Series, 1, 2, 3, 6, 7, 8, 12, 13, 34, 47, 48. Partly geological. (SIR. J. PRESTWICH). n.d.

NORFOLK.

Diss.—A Plan of Diss Mere taken June, 1835. (J. S. TUXFORD). With sections. Scale, an inch to about 35 yards. (Copy).

Norwich.—A. W. Morant's Map. (H. B. WOODWARD). 1:3960. 1875-78.

NORTHAMPTONSHIRE. (See also Lincolnshire).

Rockingham Forest.—Map of the Inliers of Little Oakley and Brigstock in the Oolitic District. (J. W. JUDD). Scale, 6 inches to one mile (enlarged from one-inch map). About 1870.

OXFORDSHIRE. (See Middlesex).

PEMBROKESHIRE. (See Glamorganshire).

SHROPSHIRE.

Shropshire.—One-inch Map, Old Series, 61, N.E., S.E. Geological in part. (SIR J. PRESTWICH). n.d.

SOMERSET. (See also Devon).

Bath.—W. Lewis's Post Office Directory Map. Drift deposits. (H. B. WOODWARD) 1:9560. 1871.

Mendips.—Three copies of Ancient Plans of the Mining District. n.d.

SUFFOLK. (See also Middlesex).

SUFFOLK.—Map of the Soils, prepared for H. Raynbird's "Farming of Suffolk," *Journ. R. Agric. Soc.*, viii. 262, 1847. (S. P. WOODWARD.)

SURREY. (See also Middlesex).

Croydon.—Baldwin-Latham's Plan. (W. WHITAKER). 1:15,000 approx. n.d.

London to Brighton.—Horizontal Geological Section. (J. FAREY). 1807.

SUSSEX. (See also Surrey).

Coast Erosion.—1. Goring to Rottingdean. One-inch Map, New Series, 318, 333 (R. B. GRANTHAM). 1885. 2. Bexhill to east of Hastings.—Six-inch Map, Sussex 71.

WILTSHIRE. (See Middlesex).

WORCESTERSHIRE. (See Gloucestershire).

LUNDY ISLAND.

Geological Map with Horizontal Sections. (R. ETHERIDGE). 1:9050 approx. 1854.

SCOTLAND.

Raasay Island, Southern Part.—Geological Map, with Horizontal Sections. 1:27,000. (SIR A. GEIKIE). 1857).

GUERNSEY.

Geological Map of the Island. (W. RUSS). 1:18,000 approx. n.d.

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## *INTRODUCTION.*

In England and Wales work has been continued in Devon and Cornwall, Pembrokeshire, and in the midland counties of Derbyshire and Nottinghamshire.

In the West of England the surveying of the Lizard area has been completed, while work has proceeded in the north along a line stretching from Boscastle eastwards, through Launceston, to Tavistock. All the more important mining tracts in Devon and Cornwall have now been surveyed on the six-inch scale. In Pembrokeshire the work of surveying the coalfield and adjacent areas has been carried westwards to the sea, and but little remains to be done to complete the survey of the South Wales Coalfield on the six-inch scale. In the Midlands the field work has proceeded northwards in the Chesterfield and Ollerton Sheets.

The original survey of Scotland has been continued in the neighbourhood of Glencoe and Ben Nevis, in the island of Mull, and in the counties of Caithness, Perth, Inverness, and Argyll. The revision of the Carboniferous areas in the Midland Valley has also been proceeded with.

### Pre-Cambrian Rocks and Crystalline Schists.

Crystalline schists of sedimentary origin, belonging to the Highland Metamorphic series, have been surveyed in the Ross of Mull, between Glencoe and Glen Nevis, and on the east and west sides of the great granitic complex of the Moor of Rannoch.

The work in the area between Glencoe and Glen Nevis, when considered in connection with that of former years in the neighbourhood of Glen Etive, is of exceptional interest from a tectonic point of view. In the Summary of Progress for 1905 it is stated (p. 91) that the structure of the district about Dalness, immediately to the north of the Cruachan mass of granite, is evidently that of a huge overfold, the limbs of which dip gently westwards and are at least three miles in length (from trough to crest). The later work, to the north of this area in the region between

Loch Leven and Glen Nevis, has confirmed, extended, and somewhat modified the view here expressed. The sequence in the lower limb of the recumbent fold of Glen Etive is now regarded as incomplete, owing to a plane of disturbance to which the term *fold-fault* is applied. As this plane of disturbance is followed towards the north the beds, which are assumed to be missing in the Glen Etive fold, make their appearance, and, finally, the fold becomes symmetrical. This assumed fold-fault differs in two important respects from the thrust-planes of the north-west of Scotland; it is distinctly related to a fold and is not marked by the occurrence of crushed rocks or mylonites. A question of very great general interest is therefore raised by this recent work. Are the stratigraphical difficulties, which almost every worker in the Central Highlands has experienced, due in a great measure to the existence of recumbent folds of great amplitude associated with fold-faults of the type above referred to? At present we can do little more than state the problem.

Plutonic rocks, associated with the Highland schists, but of much later date, have been surveyed in the Ross of Mull and on the Moor of Rannoch. The site of the large resevoir now being constructed by the British Aluminium Company in the valley of the Blackwater has been surveyed. It consists of the granite of the Moor of Rannoch traversed by dykes of porphyrite.

Field-work in the Lizard promontory was finished during the year, and further evidence was obtained in support of the general views expressed in previous Summaries. A new group of rocks—the Treleague quartzite—was recognised north of St. Keverne. Unfortunately this group is only seen inland, and the exposures are so obscure that its stratigraphical relations cannot be satisfactorily determined. The rocks show clastic structures under the microscope, and are, therefore, probably not referable to the same series as the more highly metamorphosed mica-schists and quartzites of Old Lizard Head, in which all such structures have been obliterated.

An area of pre-Cambrian rocks, consisting of granite, quartz-porphyry and diorite, together with rhyolites and andesites, was met with in Pembrokeshire, near Hayscastle, on the northern side of the coalfield. On the southern side the dioritic rocks of the Johnston ridge, which are of unknown but great antiquity, have been traced westward with some interruptions to the coast at Talbenny, where they may be seen resting on disturbed Carboniferous strata. Great developments of rhyolite, andesite, and basalt have also been met with, but as the age of many of these rocks is doubtful, further description is postponed until the field-work is finished.

### Cambrian, Ordovician, and Silurian.

Lower Palæozoic rocks of Cambrian, Ordovician, and Silurian age have been surveyed in Pembrokeshire. All the lithological and palæontological subdivisions described in last year's Summary have been followed westward, and in addition a definite base to the Cambrian has been recognised. The oldest Cambrian strata are referred to the Caerfai group of Dr. Hicks, and they

have been proved to rest unconformably on the pre-Cambrian rocks, which have been followed from Hayscastle to the sea at Pointz Castle. These rocks are represented on the old map as intrusive granite and porphyry.

### Devonian.

The Devonian rocks, extending eastwards from Boscastle to Brentor and Tavistock, have been surveyed and various new subdivisions have been recognised and traced, but until the more or less detached areas have been connected up no general statement can be made. The palæontology of the Upper Devonian has received some attention during the year, and new species of fossils, from Port Quin in Cornwall, have been recognised; two of these, a trilobite and a lamellibranch, have been described.

Passing now to the opposite side of the British Channel, where the Old Red Sandstone facies prevails, we have to note that rocks, belonging to the Upper and Lower divisions, have been surveyed in the neighbourhood of Milford Haven. One of the most interesting results is the recognition of the prolongation eastwards of the Benton Castle fault across the Daucleddau into the Lawrenny promontory, where it has the effect of bringing together two sets of green beds which are lithologically similar but which belong to two very different horizons of the Old Red Sandstone Series.

The Upper Old Red of West Angle Bay, on the south side of Milford Haven, is of special interest, on account of the occurrence of two marine bands near the top of the series. These bands evidently represent temporary incursions of the sea into areas where Old Red conditions prevailed and fore-shadowed the oncoming of the truly marine conditions of the Lower Carboniferous period. On this account, special attention has been paid to the lithology and palæontology of these bands.

In Scotland, rocks of Old Red Sandstone age have been surveyed in the neighbourhood of Glencoe and in Caithness. The survey of the volcanic series in the former locality is practically finished. The mapping of the different types of lava has proved that each type attains its maximum thickness in a distinct area; a fact which points to the conclusion that the different types were erupted from different centres. In Caithness, where the rocks of this age consist of sediments, one result of considerable interest has been obtained. The Achanarras fish-fauna, hitherto only known to occur in one inland locality, has been found on the coast near Latheron, under conditions which enable its position in the Caithness series to be definitely determined.

### Carboniferous.

In the west of England, Carboniferous rocks have been surveyed near Boscastle, Launceston, and Brentor. They consist of cherts, shales, and grits with contemporaneous igneous rocks. Two distinct horizons of lava and two of chert have been recognised in the neighbourhood of Launceston; but the full discussion of the results must be deferred until the detached areas

have been jointed up. The sequence at Brentor is generally similar to that at Launceston, except that no representative of the lower cherts has been found.

In Pembrokeshire, the mapping of the coalfield has been nearly completed. The chief interest lies in the nature of the disturbances which have affected the region. One of the most remarkable of these disturbances forms the southern boundary of the Carboniferous area to the west of the Daucleddau. It is an overthrust fault of variable hade. The Carboniferous rocks in front of it, that is to the north, have been greatly disturbed, and near Johnston sheared lenticles of Carboniferous Limestone occur amongst the Millstone Grit rocks. The overthrust follows a very sinuous course, due to its variable hade rather than to inequalities in the surface features, from Langum to the coast north of Talbenny where, as already stated, the dioritic rocks of the Johnston ridge, which are certainly of pre-Llandovery and, probably, of pre-Cambrian age, may be seen resting on disturbed Carboniferous strata.

Another important fault has been followed from Benton, on the Daucleddau, to the coast near Mill Haven, west of Talbenny. This fault has the effect of bringing different horizons of the Old Red Sandstone on the south against various older rocks on the north. As seen on the coast, it is an overthrust from the south, and is accompanied by much shearing.

In the Midland district field-work has been confined to the Millstone Grit and Coal Measures. In tracing the Millstone Grit series northwards in Derbyshire, special attention has been paid to the lateral changes in the nature of the deposits. Although the principal grits can be followed, it is found, as might naturally be expected, that they undergo certain changes in thickness and character.

The re-survey of the area occupied by the Lower Coal Measures to the west and north-west of Chesterfield has resulted in the introduction of much greater detail than is contained on the earlier maps, and in slight modifications of the lower boundary. The additional detail consists in tracing out the sandstone-beds, which can be followed with great accuracy in consequence of the high relief of the country and the absence of drift.

Chesterfield lies on the Middle Coal Measures, but east of the town a well-marked anticlinal fold trending north-north-west brings up the Lower Coal Measures, as shown on the old map. This fold is associated with a system of north-west and south-east faults, which do not appear to have any effect on the overlying Permian strata. On the other hand, certain north-east and south-west faults, the existence of which has been proved in the coal-mines, have been found to affect the Permian, though not to the same extent as the Coal Measures.

In Scotland the revision of the coalfields has been continued in the Airdrie and Shotts District, and in the Carron and Slamannan District. In last year's Summary attention was directed to the occurrence of marine beds near the base of the Upper Carboniferous red barren measures in Fifeshire, Midlothian, Lanarkshire, and Ayrshire. In view of the importance [redacted] this question, a careful measurement of the section exposed

in the River Calder, near Palacecraig, has been made, and the position of the marine bed in relation to the Upper Coal of that district has been definitely determined. At this locality red and mottled strata occur below the marine bed, although they are not found immediately above it; the bed, therefore, does not rigidly coincide with the lower limit of the red measures.

Some interesting evidence bearing on the relation of the intrusive sheets of dolerite or whinstone, as it is locally termed, to faults has been obtained. It points to the conclusion that the igneous magma may in certain cases have taken advantage of pre-existing fault-planes, and, therefore, that the coincidence of whin-scarps with faults cannot be regarded by itself as conclusive proof that the faulting is later than the intrusion of the whin.

In the northern part of Lanarkshire, about Greengairs and Longriggend, as is well known, certain seams of bituminous coal pass first of all into steam-coal and finally into anthracite. This change is generally regarded as being due to a concealed body of whin, notwithstanding the fact that where the effect of whinstone on coal can be directly observed it does not result in the formation of anthracite. A consideration of such analyses as are available of the different types of coal met with in this area does not support the above view. The percentage of ash in the anthracite is either equal to or less than that contained in the bituminous coal; not greater as it should be if the anthracite were formed from the bituminous coal by the driving off of volatile matter. The facts from this area, so far as they are known, are in accord with those described in the recently published memoir on the Coals of South Wales. They point to the conclusion that the lateral change from bituminous coal to anthracite is in some way or other connected with original differences in composition.

## Permian and Trias.

The Permian rocks, which have been surveyed during the year, lie to the east and south-east of Chesterfield in the counties of Derbyshire and Nottinghamshire. A basal breccia is followed by grey marls, and these, again, by the main mass of magnesian limestone which forms a bold escarpment facing the exposed part of the coalfield. Above the limestone come red marls with red sands, sandstones and thin bands of impure dolomite. Representatives of an upper magnesian limestone, less pure than the main mass, occur in the positions indicated in the old map.

The grey marls at the base of the Permian yield a soil indistinguishable from that of the Coal Measures, so that the boundary between the two formations, notwithstanding the great unconformability which separates them, cannot in all cases be traced with confidence. These marls have occasionally been mistaken for Coal Measures in the records of certain shafts sunk through the magnesian limestone, and small tracts of clay in the valleys at Stony Houghton and near Scarcliffe, mapped as inliers of Coal Measures by the early surveyors, are probably formed of them.

Attention has been paid to the structure of the main mass of magnesian limestone. It consists of two fairly distinct types of deposit—an evenly bedded flaggy type and a more massive current-bedded type which takes the form of arches or elongated domes, the axes of which run, approximately, north and south.

Considerable areas of Bunter and Keuper have been surveyed in Nottinghamshire, but no new features have been met with.

### Jurassic Rocks.

No area of Jurassic Rock has been surveyed during the year, but the fossils collected some years ago, from the borings and sinkings for coal at Dover, Brabourne, and Penshurst, have been critically examined. A few of the more important results will be found recorded in the following pages. A boring in the Fullonian and Inferior Oolite, at Stowell in Somersetshire, is described in an Appendix.

### Cretaceous Rocks.

A most unexpected discovery of Cretaceous fossils has been made in Caithness. They are at present known only from one quarry, and whether the rock (sandstone) in which they occur is in place or is a large transported boulder is uncertain. With the exception of *Pecten orbicularis* the fossils are not specifically determinable, but the following genera have been recognised:—*Craspedites*, *Hamites*, and *Crioceras*. They are probably of Neocomian age, and certainly represent the most northerly occurrence of such rocks in the British Isles.

### Tertiary Rocks.

A small area consisting of lavas and intrusive granophyres has been mapped near Salen in the Isle of Mull.

### Pleistocene and Recent.

The superficial deposits have been surveyed in all areas where work is going on.

Devon and Cornwall are, as is well known, entirely devoid of glacial drift, its place being taken by accumulations of local detritus on slopes, known as 'Head.' In last year's Summary attention was directed to the occurrence of considerable masses of this material at high levels in the granitic area of Bodmin Moor and to the possibility of its containing wolfram and tin in localities where it has been formed by the weathering of ore-bearing granite. Prospecting is now being carried on, and wolfram is often found to be abundant near the northern margin of the granite.

In Pembrokeshire boulder-clay is scarce, but sands and gravels cap many of the minor elevations. Isolated boulders indicating a travel from the west or north-west have been noted in the area surveyed during the year. Traces of the well-known raised beach have been found on the north side of Milford Haven.

In the Midland district scattered boulders and fluvio-glacial deposits have been observed in a few places, but large tracts are entirely free from drift. In the driftless areas slight differences in the hardness of the rocks are reflected in the topography, especially on the slopes, and it becomes possible to map with great accuracy the thin beds of sandstone in the Coal Measures and the skerries in the Keuper.

The glacial history of that portion of the Isle of Mull which has been surveyed during the year is exceptionally clear. The mainland ice, descending from Loch Linnhe, split into two streams, one of which passed to the north and the other to the south of the central mountain-group. The northern stream skirted the Sound of Mull as far as Salen, where it turned south-westwards into Loch-na-Keal. The course of this ice-stream is marked in the clearest possible manner by the grooving and striation of the rocks and by the *roches moutonnées*. At a later date a local glacier descended Glen Forsa, crossing the direction of the earlier current nearly at right angles, and leaving evidence of its existence in striations, groovings, and morainic deposits.

A similar sequence of events has been established for the region about the head of Loch Rannoch, the main ice stream in this case having passed eastwards from the area now occupied by the Moor of Rannoch.

# I.—ENGLAND AND WALES.

## I. FIELD-WORK.

Geological surveying was continued in the three districts which had been taken in hand during previous years, namely:—

1. Midland district under Mr. G. W. Lamplugh.
2. Southern district under Mr. C. Reid.
3. South Wales district under Dr. A. Strahan.

In addition to the ordinary field-work, Dr. Strahan and Dr. Gibson examined the cores of deep borings for coal in Denbighshire and Cheshire. Several borings and sinkings for coal in the Midland district, outside the area in course of survey, were investigated by Dr. Gibson.

A boring for water at Stowell, in Somerset, which threw new light on the Fullonian group of strata, was examined by Mr. J. Pringle.

Mr H. B. Woodward made further notes on the branch-line of the Great Western Railway between Limpley Stoke and Camerton, near Radstock, while Mr. G. Barrow continued his examination of the new cuttings on the branch between Bicester and Aynho.

The Bovey and Lee Moor clay-districts were visited by Mr. Howe, and specimens and photographs were obtained.

The sheet explanation on "The Country around Newport" (Sheet 249), having been nearly sold out, the ground was revisited, and notes were made on the new sinkings for coal, railway cuttings, &c., by Dr. Strahan, with a view to the preparation of a new edition.

### 1.—Midland District—Derbyshire and Nottinghamshire.

Mr. G. W. Lamplugh, F.R.S., District Geologist.
Mr. J. B. Hill, R.N.
Mr. W. Gibson, D.Sc.
Mr. C. B. Wedd, B.A.
Mr. B. Smith, M.A.
} Geologists.

The field-work of the year covered a belt of country stretching from the valley of the Derwent on the west to the valley of the Trent on the east, this belt being included within the northern portions of Sheets 112 (Chesterfield) and 113 (Ollerton), and the southern part of Sheet 100 (Sheffield) of the one-inch (new series) maps.

The western part of the belt, mapped by Mr. C. B. Wedd, consisted mainly of the Millstone Grit Series and the Lower Coal Measures; the Middle Coal Measures, east of this ground, were mapped by Dr. W. Gibson, whose area also included the Permian escarpment; the main outcrop of the Permian rocks, together with that of the Bunter, was surveyed by Mr. J. B. Hill; the Keuper Marl and Waterstones, with the alluvial deposits of the Trent, forming the eastern part of the belt, by Mr. B. Smith; and two detached tracts, respectively in the Permian and Trias, by Mr. G. W. Lamplugh.

## MILLSTONE GRIT SERIES.

In tracing the Millstone Grit Series northward, Mr. Wedd finds the general succession observed further south to continue, with the following members in descending order:—

| | |
|---|---|
| Rough Rock | |
| Shale | |
| Thin grit (Longshaw? Grit) | Middle Grit Group. |
| Shale | |
| Chatsworth (Belper) Grit | |
| Shale | |
| Kinderscout Grit | |
| Shale Grit Group | |

But while the Millstone Grits individually exhibit a remarkable persistence throughout a large area, they are liable to great though gradual variations of texture and thickness. Partial degeneration, with lateral passage into sandy shale, is a common phenomenon in them. In fact throughout this district it is one of the usual methods by which a decrease of the grit-beds is brought about. Apart from direct loss of thickness of gritstones, some loss of total thickness of strata may take place.

*Kinderscout Grit.*—This grit maintains in part a coarse-grained and pebbly character to a short distance north of Matlock, but afterwards gradually loses its pebbly nature and assumes a finer grain. At the same time it becomes liable to degenerate at some horizons into sandy shale, and ceases to present such a bold and clear-cut escarpment as characterizes it further south. At Beeley it has split into several alternating beds of fine grit and grey sandy micaceous shale, and its outcrop rises in a series of rather ill-defined terraces; while in Chatsworth Park its feature becomes very poor, and can scarcely be traced. Above Baslow it again consists of several beds of massive fine grit with intercalated shale in a terraced escarpment, which weakens northward, until at Curbar it is completely buried under the mass of screen-material from the overlying Chatsworth Grit. At this place it is represented upon the old map as cut off by a fault.

It is evident that this splitting and weakening of the Kinderscout Grit, until only a single bed of it remains strong enough to produce any escarpment, affords the true explanation of its striking diminution at Chatsworth, where Green's suggestion of diminished deposition of the grit upon an elevated portion of an uneven bottom* is clearly out of place.

*Chatsworth Grit.*—Similarly, the lower half of the Chatsworth or Belper Grit of Sheets 112 and 125 often shows variation, with a tendency towards splitting off and local weakening, as well as a general vacillation between grit and shale at its base. This is seen at its outcrop between Beeley Moor and Chatsworth, where the lower part can be traced for some distance north-westward as a separate member, and is then lost. It is the upper pebbly part alone that crowns the fine escarpment above Chatsworth; that is to say, the line that would naturally be taken as indicating the base there lies at a considerably higher level than the base of the grit

* Geology of the Yorkshire Coalfield, *Mem. Geol. Surv.*, 1878, p. 30 and Pl. I.

below Beeley Moor. But in the Chatsworth escarpment small exposures of fine-grained micaceous grit are seen much lower down, and evidently represent the lower member of Beeley Moor. At the north end of the escarpment, shortly before it descends to the valley of Bar Brook, dark shale appears to have been dug just below the pebbly upper grit. Further north, in Baslow and Curbar Edges, it is still the coarse-grained and pebbly upper member that forms the steep and rugged scarp. But a great thickness of fine-grained grit below this, with a suggestion of shaly partings, has been quarried at the south end of Baslow Edge. Hence it seems that the two members of the grit have come together again, the lower one in these escarpments being in great part buried under talus from the upper, which forms a wall-like edge, of which the bottom might easily be mistaken for the base of the whole grit.

*Rough Rock.*—The outcrop of the Rough Rock, divided by a parting of softer material, produces two rocky edges on Beeley Moor, and maintains two distinct members for some distance northward; but the parting becomes less evident until it ceases to be traceable before reaching the main road to Baslow.

*Marine Fossils.*—Some ground exists for supposing a more frequent intercalation of marine fossiliferous horizons in the Millstone Grit Series as it is followed northward. In the area previously surveyed no horizon of marine fossils had been found between the top of the Kinderscout Grit and the base of the Shale Grit group. Hence some interest attaches to the occurrence of abundant *Glyphioceras bilingue?* (Salt.) and *Posidoniella* in shale exposed not far below the attenuated Kinderscout Grit and above the Shale Grits in Chatsworth Park, half a mile north of the House.

### LOWER COAL MEASURES.

The general sequence of the Coal Measures below the Silkstone (Black Shale) Coal remains fairly constant to the succession in the southern part of the district, except that the Kilburn Coal does not persist, at any rate, as a seam of any consequence. On Gibbet Moor east of Chatsworth it has been necessary to modify the mapping of the Rough Rock and to include in the Coal Measures some of the area assigned to the former on the old map. A small coal-seam lies on or near to the top of the Rough Rock as usual; while some attempt has been made to work another seam on Gibbet Moor not far below a higher, rather gannister-like sandstone, which forms an outlier. The higher coal seems to be the Alton, which has been recognized as cropping out in Blackleach Brook east of Baslow, where it has the usual marine bed of black shale full of goniatites of the genus *Gastrioceras*, and *Pterinopecten*, immediately above it, and four feet of gannister sandstone as its floor. The seam was worked there several years ago. Its outcrop can be traced for some distance northward and southward. It is noteworthy that its distance above the Rough Rock, which had increased northward from less than 70 feet near the southern margin of the coalfield to about 280 feet at Ambergate and approximately 300 feet at Alton, has decreased here apparently to less than 100 feet.

The outlying sandstone above the upper coal on Gibbet Moor crops out again east of Umberley Brook, where at a somewhat higher horizon a massive sharp quartzose sandstone, rather coarser in grain than is usual in coal-measure sandstones of the district, can be traced northward across Ramsley Moor. Small pits along its outcrop attest former attempts to quarry it. It has the aspect of a better building-stone than the generality of coal-measure stones in the neighbourhood.

The succeeding measures, chiefly shales with the three small coals indicated on the old map further south, one of them probably representing the Naughton Coal, are buried under the peaty deposit of Leash Fen.

The Wingfield Flagstones come on eastward in a series of escarpments rising considerably above the underlying shales. The difficulty of defining the upper limit of these flagstones is increased by the apparent absence of the Kilburn Coal, and by the greater aggregation of sandstones in the succeeding measures than is the case further south. In fact in the neighbourhood of Barlow the measures from the Wingfield Flagstones upward to the Silkstone (Black Shale) Coal show a rapid succession of small sandstone-outcrops, which, owing to the unusually great elevation above the general level of stream-erosion, the complete absence of all trace of drift, and the comparative freedom from faulting, can be traced in considerable detail for long distances. The sandstone overlying the Silkstone Coal makes a bold escarpment recognizable throughout the district. A seam apparently a little more than 50 feet below the Silkstone Coal was worked at Cutthorpe as the Mickley Coal; another, about 150 feet lower, has been worked at Ingmanthorpe.

### MIDDLE COAL MEASURES.

Dr. Gibson notes that east of Chesterfield the Coal Measures rise up in a well-defined anticline, of which the axis (as mentioned in the Summary for 1905, p. 20) coincides with the high ground of Calow and Brimington Common. During the present year this disturbance has been traced northward to Whittington Moor (Sheet 100 N.S.) and southward to its termination between Tibshelf and Teversal. Between Brimington Common and Whittington Moor the anticline, except where it is breached by the river Rother, continues as a belt of ground elevated in a general north and south direction above the surrounding country. The strata are highly inclined on both flanks, and the symmetry of the anticline is unbroken. On the east side, between Cock Alley and Arkwright Town, the Great Central Railway (formerly L.D. and E.C.Ry.) reveals an almost continuous sequence from the Silkstone to the Top Hard coals, affording the most illustrative section of Coal Measures to be found anywhere in the Derbyshire Coalfield.*

Between Calow and Tibshelf the anticlinal disturbance loses its symmetrical character and is diagonally crossed by a faulted belt,

* C. Fox-Strangways, *Quart. Journ. Geol. Soc.*, vol. liv., 1898, pp. 163–167.

which can be resolved into a major fracture on the west, having a large downthrow west, and a second fracture on the east with a large downthrow east.

To the south-east of Calow the main anticline sags down, and around Temple Normanton the line of disturbance is continued by a local syncline with the Williamthorpe Pits of the Hardwick Colliery situated toward the centre. A little north of Astwith the strata again assume an anticlinal form, but with the boundaries disguised by faults. At Hardstoft the axis bends S.E. until at Teversal the strata gradually assume the general north-easterly dip of the main coalfield. That the faulting is intimately related to the folding is shown along the whole line of the disturbance, and conspicuously so between Tibshelf and Teversal, where the main faults coincide with the change in strike; but whether faulting and folding took place simultaneously is not so certain.

The faults associated with the folded belt strike NW.—SE., and in the Bolsover district two faults outside the folded area have the same direction. North of Glapwell two faults of 33 feet and 31 feet respectively, proved in the colliery workings, trend NE.—SW. When followed up to the Magnesian Limestone escarpment the NW.—SE. faults do not affect the Limestone, and are certainly of pre-Permian age. It is otherwise with the NE.—SW. faults, which possess a throw in the Permian, though much less than their throw in the Coal Measures.

The Coal Measures cropping out between the anticlinal disturbance and the Magnesian Limestone escarpment range from about 300 feet below the Silkstone Coal to about 1,100 feet above the Top Hard Coal. With the exception of railway cuttings and a few sandstone quarries and clay pits, sections are rare and no new coalpits are being sunk in the district. The conditions have, therefore, been unfavourable for obtaining new information respecting the palæontology of the Coal Measures. Though sections are few and far between, the sandy members retain their individuality for greater distances than further south, and in consequence the features to which they give rise afford reliable guides in mapping, and prove of great assistance in the delineation of structure and in the tracing of faults.

The chief seams worked in the exposed part of the Coal Measures are, in ascending order, Silkstone (Black Shale), Deep Hard, Deep Soft, and Top Hard; and in the Duckmanton district the three Waterloo Coals between the Deep Soft and Top Hard assume a local importance. Under the Magnesian Limestone, the Top Hard Coal is alone being raised. It retains its general qualities, and is characterised as elsewhere by the capricious occurrence of cannel at the bottom of the seam.

### PERMIAN BASEMENT BEDS.

Dr. Gibson remarks that between Teversal and Oxcroft the Magnesian Limestone surmounts the Coal Measures in a bold escarpment, except at Ault Hucknall where the continuity of the feature is broken by a broad but shallow depression occupied by

the marls and calcareous flags occurring at the base of the Permian. To the S.E., near Rowthorn (Hardwick) station, a tributary stream of the Meden cuts down to the Coal Measures, and in the railway-cutting near the station the basal breccia of the Permian is clearly exposed. The breccia, of the usual Nottinghamshire type, is about one foot thick and is overlain by about 10 feet of pale-grey marl containing a few thin bands of argillaceous and sandy limestone.

This basal marl of the Permian furnishes a pale clay-soil indistinguishable from that of the weathered coal-measure shale, so that the two formations are not separable along the grassed slopes of the escarpment. The absence of the marl from a drainage-trench cut across the scarp-face near Hardwick Hall shows that it is impersistent westward and is probably in part replaced by thin calcareous flags separated by marl-partings. Even when unweathered the marl is not unlike the pale-blue clays of the Coal Measures, and in some of the older records of shafts sunk through the limestones to the Coal Measures it has been included with the latter, while on the other hand, several feet of Coal Measures have been occasionally grouped with the Permian. In the mining shafts the Permian marl is usually fossiliferous, as at Sherwood Colliery, Mansfield, and can thus be discriminated from Coal Measures.

Mr. Lamplugh observes that the lower flaggy beds of the Magnesian Limestone series occupy the steep slopes of the Meden valley above Pleasley, and are prolonged eastward in the bottom of the valley up to the beginning of the rocky gorge of Pleasley Vale, which is excavated through the overlying massive dolomites. The flaggy bedding of the lower series is accentuated by partings of red marl; and the thin limestones frequently show a nodular concretionary structure which imparts a conglomeratic or brecciated aspect to some of the bands, the nodules being dominantly calcareous and only slightly dolomitic. The thickness as well as the composition of these beds is very variable, but at their outcrop it appears rarely to exceed 20 feet. The presence of clays below the exposed beds is indicated by the numerous springs; and from the evidence of the section near Rowthorn Station, mentioned above by Dr. Gibson, it may be inferred that these clays lie above the base of the Permian, and do not belong to the Coal Measures, as was previously supposed. Therefore the tracts of clay in the valleys at Stony Houghton and near Scarcliffe, shown as small inliers of the Coal Measures on the old map, are now represented as part of the Permian.

### MAGNESIAN LIMESTONE.

Mr. Hill describes the outcrop of the Magnesian Limestone as having a maximum breadth of about 5 miles between its escarpment at Bolsover and Market Warsop. The rock is composed mainly of crystals of dolomite with a very variable but usually small proportion of sand, and is generally speckled with oxide of maganese, and some calcite is almost invariably present when the rock is fresh. The crystalline texture is generally visible, but more

compact varieties occur in which the structure can only be distinguished with the aid of a lens. When fresh the rock is of a pale grey colour, but on decomposition, hues of yellow, orange, pink, and red prevail. Its bedding structures are markedly diverse, and suggest that its individual grains have been swept as such over the sea bottom and deposited as a true sediment. The flaggy planes show a marked want of parallelism and a high degree of false bedding. One of the most interesting features, however, attending its deposition is the development of arches or elongated domes, with axes approximately north and south, the weathering of which has given rise to long hummocky features, rudely parallel to the strike of the dolomite band. These domes vary in size and declivity of slope, the latter occasionally reaching as high an angle as 20°. In some cases these domes might be confounded with anticlines, but that they really mark a phase in deposition is clear, as their base often rests on beds of horizontal dolomite. Its deposition was so irregular that the dolomite cannot be broken up into a lithological sequence that will hold good even over this limited tract. For convenience, however, a rough differentiation may be obtained by separating the central zone, in which false bedding and doming is a striking characteristic, from the upper and lower zones in which more regular and thin-bedded flaggy structure generally prevails. These distinctions are, moreover, reflected in the topography, the central zone forming hummocky ground flanked on either side in strong contrast by smooth tracts. The upper flaggy type, however, is not always present, and in these cases the false-bedded and domed characters extend to the top of the division. The Magnesian Limestone often passes up into the overlying Permian Marl, a thin deposit of shaly dolomite forming a connecting link and indicating conformity between them, these passage beds being well represented in the railway cuttings at Shirebrook. Similar shaly bands are sometimes seen in the heart of the dolomite at various horizons, forming lenticles that were laid down in shallow basins of the latter deposit. At the surface, beds of this character break down into a red clay, but in most cases the lenticles are too small to be mapped. In the valley to the south of Scarcliffe, however, a small patch of red clay has been mapped on the border of Roseland Wood, and another at Bolsover Moor.

The dolomite yields soils of very diverse character. In some tracts they are thin and abundantly strewn with dolomitic fragments, while elsewhere the rock may have decomposed for a depth of several feet into dolomitic sand, forming a very light soil; but its dominant character is a stiff soil that often approaches in tenacity the clay soils of the Permian Marl. This gradation from light to stiff soils probably has less relation to diversity of composition of the dolomite than to the phases in its decomposition.

Mr. Lamplugh notes that all the structural peculiarities of the Magnesian Limestone mentioned in the above description are exemplified in the Pleasley district, where the formation is exposed almost continuously across its outcrop in the deep cuttings of the G.N.Ry. between Pleasley and Shirebrook, as well as in

the craggy walls of Pleasley Vale and in the cuttings of the Midland Railway south of the Vale. A thick band of red sandy dolomite, or dolomitic sandstone, like that of a higher horizon at Mansfield, occurs toward the base of the massive dolomites below the Lower Mill in Pleasley Vale, but appears to be continuous only for a short distance.

### PERMIAN MARL.

Mr. Hill finds that the red marls which overlie the Lower Magnesian Limestone are sometimes associated with red sands and sandrock, and thin bands of impure dolomite are frequently intercalated. Bands of pale grey colour occasionally alternate with the red clay, especially in the vicinity of the thin dolomite seams. To the south of Cuckney the marls are thin and form discontinuous outcrops, while to the north of that locality the band is thicker, due to its inclusion of red sands. The arenaceous types are chiefly represented in the district west of Holbeck Woodhouse, the eastern portion of the band, lying mainly in Welbeck Park, being argillaceous. This implies an ascending sequence from the sands to the marls unless there is a lateral change in the character of the deposit. The presence of these sands amongst the marls recalls similar conditions in the Pleasley and Mansfield districts further to the south, where dolomitic sandstones occur among the purer dolomites.

### UPPER MAGNESIAN LIMESTONE.

Mr. Hill observes that this division is represented in the vicinity of Collingthwaite and Holbeck Woodhouse by two small outliers that were recognised by the late W. T. Aveline. They overlie the red sandrock associated with the Permian Marl, and the dolomite is of a different type from the Lower Magnesian Limestone. In all probability it represents a thickening of the thin dolomitic bands that are associated with the marls in the district further south. No clear exposures were seen, so that its thickness is uncertain, but is probably not greater than 10 or 12 feet.

### BUNTER.

Mr. Hill remarks that the Lower Mottled Sandstone in its outcrop between Welbeck and Market Warsop consists of soft red sandy beds, while types intermediate in character between sands and marls are exceptionally represented. Small lenticles of marl occur, and large pebbles are occasionally scattered in the deposit, in which also narrow seams composed of small rounded and angular fragments may be seen. It rests in some places on the Permian Marl and in others on the Magnesian Limestone, so that there is either an unconformity or a marked overlap at its base. It passes up into the Bunter Pebble Beds which occupy the forest lands between Welbeck and Edwinstowe and consist of false-bedded red sand irregularly divided by bands of pebbles. Tiny lenticles of red clay are occasionally present, and there are, exceptionally, larger patches of clay in which pits have been opened. The pebbles are distinguished by their polished surfaces, which suggest torrential conditions; but if derived from

pre-existing conglomerate, as some writers have advocated, their smoothness might be ascribed to the double process of attrition. In this area they are mainly siliceous, and cherts occur in relative abundance. Although quartzites and banded quartzitic rocks are largely represented, schists either of sedimentary or igneous origin are absent or rare; on the other hand, siliceous breccias such as frequently line the walls of mineral veins are plentiful.

### KEUPER WATERSTONES.

Mr. Lamplugh finds that the base of the Waterstones in the northern part of Sheet 113, between Boughton and Bothamsall, presents the same characters as in the country farther southward described in last year's Summary (p. 18). An impersistent basal conglomerate, only a few inches thick, is overlain by greyish-green shaly clay, 15 to 20 feet thick, passing up into red shaly clays, loams, and sandstones of the usual type. In colour, composition and thickness these green beds at the base of the Keuper recall the Tea-green Marl at the top of the division, while in every intermediate part of the series the green colour is confined to bands of comparatively insignificant thickness. The soft brown sandstones above the bottom clays are well seen in the village of Kirton, where they are more massive than usual and have been quarried.

Mr. Smith in mapping the upper part of the Waterstones in a northerly direction from Eakring, finds them to consist of variegated sandy micaceous flags and shales with a considerable amount of intercalated marl to which the typical thin red sandstones are markedly subordinate. South-west of Markham Clinton, however, a strong development of sandstones was found quite close to the base of the overlying Keuper Marls. The upper flaggy beds occur in several inliers exposed by small dip-streams flowing in an easterly direction to the Trent.

### KEUPER MARL.

The skerry belts described in last year's Summary were found by Mr. Smith to be especially persistent in the lower 200 feet of Keuper Marls and afforded a useful guide, not only to the general structure, but also to the detection of the Waterstone inliers mentioned above. Between Moorhouse and Barrel Hill there are indications of small disturbances following the direction of the dip. The two types of sandstone (skerry) recognised further southward were again easily detected, the change from one to the other being fairly sharp.

Gypsum, of the fibrous variety, was met with at several horizons, more particularly in association with skerry belts which contain building-stone like that of Maplebeck, Laxton and Tuxford. Gypsum also occurs in the river bluff north of North Clifton where the face of the cliff is cut up by old workings.

Certain belts in the upper half of the marls weather to a light loamy soil, due to some extent to the breaking down of rather loosely cemented sandstone and admixture with the marl. Soils of this description cover the dip-slopes near Crow Park Station and North Clifton.

## GLACIAL.

Mr. Lamplugh observes that as the work has been carried northward in the Midland district, the deposits recognisable as of Glacial origin have become more and more scanty, although, as mentioned in last year's Summary, the presence of a few isolated patches seem to imply that at least the greater part of the area has been glaciated. Most of the country surveyed during the past year showed no trace of drift, and nowhere contained any deposit which could be definitely mapped as Boulder Clay. Yet the situation and composition of certain patches of gravel mentioned below imply their Glacial origin.

Mr. Wedd, in mapping the high ground in the west, between the Derwent Valley and that of the Hipper, has seen no trace of glacial *débris* on the elevated Coal Measures at and westward of Barlow, except that on the lowest Measures of Gibbet Moor, at elevations varying from 900 to 1,000 feet, numerous small and some large boulders of coarse-grained and pebbly grit are met with in such a position as to suggest glacial re-distribution; for they belong evidently to the Rough Rock, the outcrop of which is separated from their present position by a depression in the lowest shales of the Coal Measures.

Dr. Gibson notes that in the valley of the Doe Lea and over the margin of the Magnesian Limestone plateau on the east, as well as on the elevated Coal-measure ground on the west and in the Rother Valley between Sheepbridge and Stavely Town, there is a complete absence of Glacial deposits and no trace of their former existence.

Mr. Hill finds that the tract between Bolsover and Edwinstowe is scantily and unequally overspread with pebbles derived from the Bunter, along with occasional small erratics of Carboniferous sandstone and igneous rocks. Besides this thin cover of gravel, which is common alike to the high ground and the slopes, there occur in the valleys of the Poulter and the Meden a few mounds composed of sand and gravel in which erratic blocks of the above-mentioned varieties are incorporated. At Cuckney a large mound rises out of the very bottom of the valley, and has been banked against one end of a small ridge of Bunter sandstone. Within half a mile of this locality, at Shireoaks Hill Farm, a long ridge of gravel skirts the higher slopes of a tributary valley. Further down the Poulter, the valley alters its direction, and is joined by a smaller hollow that forms the site of Welbeck Lake; and near this confluence and in the vicinity of the bend a group of five mounds, all approximately at the same level, appear at Cat Hill Plantation and Pitiful Hill Plantation, the furthest of which is nearly half a mile distant from the bed of the valley.

In the valley of the Meden a large mound occupies a corresponding position on its lower slopes at Elksley Hill Plantation (half a mile west of Gleadthorpe Grange), at the bend of the valley and just where a tributary basin becomes confluent with it. It is evident from the close correspondence in the position of these mounds in their relation to the valleys that they were laid down subsequent to the inauguration of the present drainage system, s not only are they situated on the lower slopes of the valleys, bt

at approximately the same level above Ordnance Datum. Their shape, moreover, and mode of distribution suggest that they are of fluvio-glacial origin, while their preservation in the valleys points to the conclusion that they mark the final stages in the glaciation of the area.

Mr. Lamplugh remarks that the sides of the valley of the Maun and Meden between Haughton and Lound Hall are fringed with coarse gravel which on the south forms the capping of a ridge between the main valley and that of a tributary. This gravel is probably of the same age as the late-glacial flood-gravels of the Trent discussed in the recently published "Newark and Nottingham" memoir (Sheet 126).

Mr. Smith notes that the Keuper area proved to be on the whole as free from drift as that surveyed last year. In the neighbourhood of the high-lying patch of drift between Kneesall and Kersall, described in last year's Summary (p. 22), a second mass of sandy gravel of less extent, at an elevation of 280 feet, has been mapped south of Ompton, as well as small patches of sand at Kneesall Church and Kneesall Wood. With these exceptions the only signs of glaciation detected in this area were furnished by small patches of stony clay and some scattered boulders up to 2 feet in length.

Mr. Wedd calls attention to some features of interest on the craggy eastern slopes of the Derwent valley, which are probably connected with the later stages of the Glacial period. North of Baslow a mass of scree and boulders of large size, all derived from the pebbly Chatsworth Grit forming the brow of the valley, is chiefly accumulated along the steep upper slope, but descends, sometimes in sheets in which the individual boulders are not usually in contact, sometimes in 'boulder streams' along little drainage-valleys, right down to the alluvium of the Derwent. The same descent of scree-material is seen in the tributary valley of Bar Brook; but a projecting snout formed by the Chatsworth and Kinderscout Grits in the acute angle between the two valleys is devoid of scree, though occasional large boulders may be seen upon its slope.

The rate of waste of the Chatsworth Grit escarpment, in spite of its disintegrated appearance, is certainly very slow, and the accumulation of scree at its foot preserves the scarp from undercutting through the weathering of the shales below. The distribution of the scree-material is clearly attributable in the main to the sliding of snow-slopes subsequently to the actual glaciation of the district. In this way the projecting snout of high ground between the Derwent and Bar Brook valleys, was left almost bare owing to its longer and gentler declivity. On the boulder-strewn eastern flank of the Derwent valley, a downward creep upon the wet clay slope before it was covered with vegetation, in the period immediately succeeding the disappearance of glacial conditions, may have carried some of the material further; while in the case of 'boulder-streams' following small and perhaps more recent drainage-valleys, a later creep may have aggregated the boulders in the bottom of these depressions. The distance traversed by some of this boulder-scree is three-quarters of a mile, with a

lescent of about 600 feet, the greater part of the descent being ac-
omplished in the first half of the distance. It is clear that but
ittle deepening of the Derwent Valley has taken place since the
nain distribution of the scree-material.

## Post-Glacial.

Mr. Hill observes that the drainage of the country between the
Bolsover escarpment and Thoresby Park is carried eastward by the
Poulter and the Meden, which in the dolomite tract have exca-
vated gorges, but in traversing the Bunter occupy wide gentle
valleys. They are bordered by meagre and narrow strips of
alluvium, but there are relics of terraces considerably more exten-
sive that mark the torrential conditions that followed the close of
he Glacial period. The Meden at Market Warsop dissects a well
lefined terrace over half a mile in breadth, which reaches a height
of 20 feet above the present stream, and in which a recent excava-
ion extended to 13 feet without reaching the base of the alluvial
leposit. Indications of the extensive drainage of this period are
also afforded by dry valleys in the Bunter beds, one of which,
known as the Long Valley, between Welbeck and Clumber, was
formerly watered for at least three miles by an ancient tributary
of the Poulter.

Over the Bunter tract the alluvium consists of sand and gravel;
but in the dolomite area it is an admixture of gravel and pale clay
—both representing the disintegration of the dolomite. The
alluvium of the high terrace at Market Warsop, just referred to,
although resting on a floor of Bunter Sandstone, consists almost
entirely of dolomitic material swept out of the dolomite gorge
immediately adjacent.

Mr. Smith has mapped in the valley of the Trent a strip of
alluvium, eight miles in length, north of South Collingham,
which proves to be very similar in character to that to the south-
west described in previous Summaries. A sheet of gravel on both
sides of the valley borders the more recent alluvium, while ridges
and islands of gravel occur in places within the central flat. The
gravels become increasingly finer in grade in a northerly and
easterly direction, and contain a large proportion of sand, both
mixed with the pebbles and in bedded layers.

Near Clifton Hill the valley is so narrow that high floods in the
immediate past have carried the Trent waters eastward at this
point to find their way to Lincoln across the gravel plain. The
alluvium is 25 to 30 feet thick, and its base sinks from O.D. near
Cromwell to 15 feet below O.D. near Fledborough.

A strip of blown sand, often rising into dunes, extends for
nearly six miles upon the east side of the valley, resting sometimes
upon gravel and sometimes upon Keuper Marl. The sands were
accumulated under bygone conditions by south-west winds blow-
ing across the river-flats. Some high-level sands near Carlton
and Sutton-upon-Trent are also considered to be of æolian origin.

The dip-streams draining the Keuper Marls have narrow
alluvial flats composed principally of red loam. In a few in-
stances calcareous tufa has been deposited by the hard wate[redacted]

draining from the skerry bands, and in the flat at Moorhouse masses of tufa stand above the general level, having been stripped of their covering of peaty soil and loam. Tufa is still being deposited about the stems of reeds (*Phragmites communis*) in the small valley north of Laxton.

## 2.—Southern District—Cornwall and Devonshire.

Mr. Clement Reid, F.R.S., District Geologist.
Dr. John S. Flett, M.A., Petrographer.
Mr. W. A. E. Ussher.
Mr. George Barrow.
Mr. R. L. Sherlock, B.Sc. } Geologists.
Mr. D. A. MacAlister.
Mr. Henry Dewey.

This year saw the completion of the Lizard area, thus finishing the survey of West Cornwall. The Camelford area was also finished, and the Tavistock and Launceston map was so far advanced as to leave little doubt as to its completion during the coming field-season. Work also proceeded in Dartmoor. In order to complete the mapping of the Devonian rocks of the coast it has been necessary in addition to survey half the Boscastle sheet.

Dr. Flett and Mr. J. B. Hill have now nearly completed the memoir on the Lizard map (359); that on Padstow and Wadebridge (335 and 336) has been partly written by Messrs. Reid, Barrow, and Dewey; Mr. Ussher has nearly finished a memoir on the district around Ivybridge (349).

### Lizard Rocks.

During June and July Dr. Flett completed his survey of the Lizard district and visited the principal rocky islands and reefs laid bare at low water. The area mapped lay around St. Keverne and Coverack and includes serpentine, troctolite, and gabbro. The troctolite is well known to occur at the south edge of the gabbro in the shore section below the village of Coverack; it forms dykes which penetrate the serpentine, and are in turn cut by the gabbro: all of these are intersected by fine black dykes of olivine dolerite. A striking variety of troctolite with large white spots in a nearly black matrix occurs in the bay south of Coverack (Perprean Cove).

*The Man o' War Gneisses.*—Mr. Howard Fox and Dr. Teall showed in 1888 that the skerries and reefs off the Lizard Head consisted of striped and corrugated tonalite gneisses which are unlike any of the rocks of the mainland. Near the shore these gneisses pass into fine granulitic rocks which resemble some of the gneisses of Old Lizard Head. Dr. Flett's examination confirms these results, and he has obtained evidence that these gneisses represent a large intrusive mass which sends apophyses into the hornblende and mica schists of the Lizard; no offshoots of this series, however, can be proved to cut the serpentine. The Man o' War gneisses, accordingly are an integral portion of

the Lizard complex; they belong to the "older granites" mentioned in this Summary last year (p. 26). As distinguished from the later granites of the "granulitic series" these older acid gneisses have the intense foliation which is characteristic of the hornblende schists. The later granites though often gneissose, cut this early foliation and are not affected by it. Often a blending of the gneiss and hornblende schists takes place at their junctions, no doubt partly the result of movement, but partly also due to *lit-par-lit* injection. These phenomena are very clearly seen in the reefs below the lifeboat house at Polpeor, where the margin of the gneiss is so mingled with the schists that it is hardly possible to separate them. Elsewhere the gneiss forms excellent sills, as at Old Lizard Head.

These facts are of some importance in the interpretation of the history of the Lizard rocks. They show that before the serpentine was injected there was already a well developed foliation in the older rocks, due to an early series of movements, an opinion which Professor Bonney has always strongly maintained. They also show that, as was stated in this Summary for last year, the development of foliation in the Lizard rocks was a complex process, and was accomplished by stresses and movements which were repeated in several stages.

*The Treleague Quartzite.*—A group of sedimentary rocks which there is every reason to believe are distinct from the mica schists and granulites of the Old Lizard Head has been found occupying a long narrow strip of ground a little to the north of St. Keverne. They lie at the north edge of the gabbro and are very badly exposed as the area is well cultivated and the rocks are deeply rotted. The only type which is found in a fresh condition is a fine grey quartzite, with clastic structures by no means badly preserved though the rock is somewhat granulitic. A curious feature of this quartzite is the presence of very fine greenish needles which occur not only in the matrix, but also penetrate the clastic grains of quartz. The quartzite is very hard and splintery, and from its proximity to the gabbro it was suspected that these needles might be sillimanite produced by contact alteration, but in hydrofluoric acid they are completely dissolved, and it is probable that they are really hornblende. Now this Treleague quartzite differs from the quartzites and granulites of the Old Lizard Head series in the preservation of its clastic structures, for the latter are always in a thoroughly granulitic condition. It is a metamorphic rock, but not so highly metamorphic as they are. Further evidence that the Treleague quartzite belongs to a distinct group is the absence throughout the area it occupies of mica schist, green schist, hornblende schist, and epidosite, which always accompany the quartzites of the Old Lizard Head series. It is, however, an older rock than the gabbro, as masses of fine gabbro and epidiorite are found in association with it, and unless the whole area is a crush breccia, they must be regarded as intrusive into the sedimentary rocks. It is very unfortunate that the exposures are so obscure and that this series is nowhere seen in the coast sections, as the stratigraphical position of this group will have important bearings on a very obscure part of the Lizard history.

### DEVONIAN.

The Devonian and Carboniferous region extending from the coast near Boscastle, eastward to Brentor and Tavistock, is now in great part mapped; but until the whole is connected it is impossible to speak with confidence as to the relation of the Carboniferous to the Devonian rocks. The coming reason will see the completion of this area; but it is a difficult and much faulted one, with disturbances running in several directions. Under these circumstances we will only refer now to points that have come out clearly in the mapping. Perhaps the most important of these points is the advance that has been made in the working out of the Upper Devonian and Carboniferous successions.

The Upper Devonian subdivisions noted last year as occurring in the region near Camelford have been traced by Mr. Dewey southward and eastward for a considerable distance; but this area is so complicated by faulting, thrusting, and metamorphism that it is difficult to describe without detailed maps. These will soon be complete, and it will be best therefore to reserve our account for the memoirs now in preparation. The relation of the Carboniferous to the Devonian rocks also cannot profitably be discussed till the mapping is finished.

### CARBONIFEROUS.

In the Carboniferous series Mr. Reid has been able to make out a succession in the lower beds, and this succession holds for some distance along the strike. The total thickness of the strata examined is probably about 500 feet; but exact measurements cannot be obtained. Where the series seems to be most complete, around Launceston, we find, in descending order, the following sequence:—

Upper lava.
Radiolarian chert.
Black aluminous shales full of pyrites and containing limestone lenticles with marine fossils.
Lower lava.
Black platy shale with thin bands of grit.
Radiolarian chert.
Devonian green slate with crinoids, &c.

In the Launceston area we do not reach anything higher than the Upper Lava.

If we begin with the lowest strata, those in contact with the greenish-grey fossiliferous Devonian slate, we find on the west carbonaceous shales, which seem to graduate southward into cherty shales and radiolarian chert. These pass upward into the black, hard, platy shales, well seen in Bangor Cornish Quarry, where they are worked for slate. This quarry shows a few thin bands of fine-grained grit; but though the regular bedding suggests a marine deposit, the only fossils that could be found were comminuted vegetable remains in small quantity. A single fragment probably belonging to *Sphenopteris* is the only recognisable plant.

The succeeding strata, well seen in numerous quarries and road-cuttings around Launceston, contain more abundant grit bands, which are both thicker and coarser in grain than those in the beds below, but the mass of the rock is still black shale.

Then follows a sheet of lava, with traces of pillow-structure, which caps the hills around Launceston, but dies out westward, and on the east of the town is thrown down by a fault to below the river-level. It may be equivalent to the Lower Lava of Brentor; but of this we are still doubtful. This lava seems to be connected with the mass mentioned by John Phillips as occurring at the bottom of Trescot [Truscott] limestone quarry, where a few fragments are still to be seen.

If this last mentioned correlation is correct, the Lower Lava is followed in upward succession by a belt of very black tender aluminous shale, full of pyrites, and containing bands or lenticles of limestone. Trescot is the locality from which Phillips records *Goniatites crenistria* and *G. mixolobus*. This aluminous shale is not seen in Launceston itself, though it is faulted down on the east of the town, where it forms gentler surface slopes than occur in other parts of the series.

Upward the black shale seems to merge imperceptibly into the thick mass of radiolarian chert which caps the hill above St. Stephen, reaching a thickness of fully 70 feet.

It will be observed that in the Launceston area we have two horizons of radiolarian chert, probably about 500 feet apart. The non-recognition of more than one chert may have led to a good deal of the doubt which has been expressed as to the true sequence in the Lower Culm.

The Launceston area has not yet been connected by continuous mapping with that around Brentor; but the succession worked out independently by Mr. Sherlock is so similar, that there seems no doubt we are dealing with the same rocks, though in this eastern district the basal chert has not yet been reached.

From Lamerton to the northern banks of the Lyd, and from Milton Abbot eastward to Marytavy the rocks are all of Carboniferous age. The general structure of the area consists of a series of folds of small amplitude pitching towards the west, and having, on the whole, an east and west direction, but trending somewhat north of east as they approach Dartmoor. The detailed structure, however, is highly complex, and the rocks are greatly folded, thrust, and faulted.

The following is the downward succession in this area:—

Upper lava.
Chert and cherty mudstone.
Black shale.
Lower lava.
Black shale with grit bands.

The top of the upper lava is nowhere seen, so that its full thickness is unknown, but fully 150 feet of it is exposed in the famous crag of Brent Tor. Outlying masses extend eastwards and westwards to the limits of the district, but the range in a north and south direction is not yet known.

The cherty beds are about 90 feet thick, and pass downwards gradually into black mudstones, and these into black shales which have yielded crinoid ossicles and in one case *Posidonomya*.

The lower lava is precisely like the upper lava except that it shows, rarely, traces of pillow structure. Its thickness is unknown, but, south of Milton Abbot, there is at least 200 feet of it. There is evidence that the lower lava never extended as far as the Lyd, and that it originated from a different vent from that which gave rise to the upper flow.

The black shales with grits, below the lower lava, are of unknown thickness. The grits, which are really sandstones, occur as thin lenticles in the shales, increasing in massiveness and coarseness downwards. The cutting on the London and South Western Railway, south of Brentor, shows these lenticles at their maximum development.

Culm rocks have been mapped by Mr. Dewey between the coast at Boscastle eastwards towards Launceston. Black carbonaceous soft slates with interbedded bands of thin grit are first met with, north of Trevalga, with outlying patches at Welltown and Grower Rock. At Willapark and in Boscastle exposures admirably reveal the flat folds into which the grits have been thrown, while at Penally Point thicker grit bands traversed by huge veins of white quartz occupy the cliff face. These quartz veins are so conspicuous that they attract the attention of most visitors to the place. The flat-folded grits are locally described as fossil trees.

The grit-bands have determined the topography of the district, and to their presence is due the bold scenery of the Vallency Valley. At Fire Beacon, on the coast, a thick band of brecciated quartz-veined chert occurs which has been described by Mr. Howard Fox and Dr. G. J. Hinde as containing Radiolaria. These cherts are succeeded to the north by greyish green spotted mudstones and shales which strike towards Otterham where they are quarried for building. The mudstones are exposed in the railway cutting near Tregray in association with soft pink and white shales in which pockets of powdery silica occur.

### GREENSTONE.

In addition to Upper Devonian and Carboniferous submarine lavas, a number of masses or sills of intrusive greenstone have been mapped by each of the geologists. Most of these are of ordinary types; but near Polyphant Mr. Dewey finds that peridotites occur over a considerable area, and a small mass of similar rock found by Mr. Reid to be intrusive in Culm rocks of Trekelland near Lezant shows that they are of Carboniferous age.

### GRANITE.

The mapping of the Dartmoor granite has been proceeded with by Mr. MacAlister; but as far as yet examined this area shows little difference from the Cornish masses described in former Summaries. In the main it is coarsely porphyritic; but ill-defined areas of finer-grained granite are also found, and this seems usually to occur as veins rather than as massive intrusions.

Mr. Barrow has obtained further evidence that the east and west trending margins of the Bodmin Moor granite near St. Cleer are often not only lodes but faults, having a large displacement. A specially good illustration of this occurs in connexion with the Darley or Henwood vein. In tracing the aureole of thermometamorphism it has been found that its breadth at Darley Villa is less than 300 yards; as the aureole round this large mass of granite normally is never less than 700 yards, and is often much more, it is clear that the fault bounding the granite has reduced the breadth of the aureole by some 400 yards. Thus the minimum possible throw of the fault seems to be some 1,200 feet.

Idocrase and garnet have again been found in calcareous rocks at Trenowth Mill, thus giving a second Cornish locality for the former mineral.

#### WOLFRAM.

Numerous trials are now taking place in the "unassorted wash" to which attention was first drawn by Mr. Barrow during the survey of last year.* They are proving that wolfram is distinctly rare in the southern part of the Bodmin Moor granitic area, though often abundant almost to its northern edge.

#### PLIOCENE.

Mr. Dewey finds that between Treligga and Boscastle a plateau feature is well marked below the 430 foot level, above which the gradient of the land rises suddenly and continues to 1,000 feet.

Near Downrow Farm several pits were dug and a seam of well-rounded pebbles associated with manganese cemented sand was found below 8-10 feet of "Head." The plateau is dissected by post-pliocene streams into steep V shaped valleys, well seen at Backways, Trebarwith, and Trevena. The plateau feature is best seen from the hills behind it. From this position the long flat shelf is seen jutting out to sea. It is remarkable that the height of this plateau feature above sea level corresponds with that described by Mr. Clement Reid as occurring at the Land's End, and is important in this connection in showing the absence of tilting in Cornwall since Pliocene times.

### 3.—South Wales District—Pembrokeshire.

Dr. A. Strahan, F.R.S., District Geologist.
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A., B.Sc.
Mr. O. T. Jones, M.A., B.Sc.
} Geologists.

The field-work of 1908 lay in the pre-Cambrian igneous rocks and Cambrian strata of the neighbourhood of Roch and Haycastle and in the Ordovician tract to the south of it. The surveying of the Pembrokeshire coalfield was carried on to the coast at Little Haven, and was completed near Newgale. In the examination of the igneous rocks and Lower Palæozoic strata

* *Quart. Journ. Geol. Soc.*, vol. lxiv., 1908, pp. 384–400.

which extend along the south side of the coalfield from the Daucleddau to Talbenny much progress was made, and the remarkable fact was ascertained that igneous rocks, of unknown, but certainly great antiquity, have been thrust over Carboniferous rocks. The surveying of the Old Red Sandstone to the south of these igneous rocks was completed as far west as Dale, and that of the Old Red region south of Milford Haven, with its infolded synclines of Carboniferous and anticlines of Silurian and Ordovician rocks, was brought within view of completion.

The following table shows in descending order the rocks below the Old Red Sandstone that are represented in the district:—

| | | |
|---|---|---|
| Silurian (part) | Ludlow-Wenlock | |
| | Llandovery | Upper Llandovery |
| | | Middle and Lower Llandovery |
| Ordovician | Bala | Slade and Redhill Beds |
| | | Shoalshook and Robeston Wathen Limestones |
| | | Dicranograptus Shales (upper part) |
| | Llandilo | Dicranograptus Shales (lower part) |
| | | Llandilo Flags |
| | Llanvirn | Didymograptus murchisoni Beds |
| | | Didymograptus bifidus Beds |
| | Arenig | Tetragraptus Beds |
| Cambrian (part) | Lingula Flags | |
| | Caerfai | Purple and green sandstones and flags |
| | | Red Shales |
| | | Green micaceous Sandstone |
| | | Quartzite and Conglomerate |
| Igneous Rocks (of uncertain age) | | Andesites, basalts and rhyolites (St. Ishmaels) |
| | | Dioritic and rhyolitic rocks (Benton and Johnston) |
| Do. (Pre-Cambrian) | | Granite, quartz-porphyry, diorite, rhyolite, &c. (Hayscastle) |

## IGNEOUS ROCKS.

### *Pre-Cambrian.*

Mr. Thomas in carrying on his researches in the northern part of the district, finds that pre-Cambrian rocks, consisting of biotite-granite, quartz-porphyry and diorite, together with rhyolites and andesites with their associated fragmental rocks, stretch in a west-south-westerly direction, as a continuous but much disturbed belt, from the neighbourhood of Hayscastle to the sea at Pointz Castle. Quartz-porphyries occur to the west of Brawdy, south of Asheston, and north of Rhyndaston: granites north of Brawdy and around Knaveston; diorite north-east of Knaveston apparently surrounded by granite; rhyolites and tuffs at Pointz Castle, in the Brandy Brook Valley, and north of Rhyndaston. As yet little can be said with regard to the relative age of the rock-types.

## IGNEOUS ROCKS.

### *Of uncertain Age.*

*Volcanic Series.*—A series of rhyolitic rocks associated with tuffs and breccias has been found by Mr. Jones to occupy a considerable area between Benton Castle on the Daucleddau and Rosemarket. They appear again to the south of Tiers Cross and near Romans Castle as mentioned in a previous Summary. A third strip has been found to extend from near Walwyn's Castle to Talbenny.

In some cases they are overlain by conglomerates and sandstones of Upper Llandovery age; in other cases the Lower Old Red Sandstone, which oversteps the Upper Llandovery rocks, comes to rest with a conglomerate on the rhyolitic rocks.

*Plutonic Series.*—The dioritic rocks which bound the coalfield on the south in the neighbourhood of Johnston have been traced by Mr. Jones with some interruptions to the coast near Talbenny where they are magnificently displayed, but the sections have not yet been examined in detail.

As indicated on the Old Series Geological map another area of plutonic rocks nearly two miles long occurs near Sardis about four miles south of Haverfordwest; these he finds to be of similar type to the preceding. Along their south side they adjoin the Benton volcanic rocks, while on the north they are overlain by Upper Llandovery rocks or Lower Old Red Sandstone, each with conglomerate at the base.

The masses of 'greenstone'—presumably intrusive—indicated on the Old Series one-inch map (Sheet 38) at St. Ishmael's, have been identified by Mr. Cantrill as a series of volcanic rocks, chiefly lavas, which fall into two types, an upper set of some 1800 feet of dark-grey and purple andesites and basalts, and a lower set of about 400 feet of white-weathering rhyolites. Their relations to the Silurian sediments above and to the Llandilo rocks below are not yet worked out.

Midland I., Skomer I., and Grassholm have been examined by Mr. Thomas and proved to consist essentially of volcanic rocks embracing rhyolites, andesites, and dolerites, interbedded with sediments of uncertain age. The sediments, which are of considerable thickness and are well displayed on Skomer I., consist of quartzites, breccio-conglomerates, red and chocolate marls or clays, and green sandstones.

## CAMBRIAN.

As a result of his examination of the Cambrian rocks, Mr. Thomas has ascertained that they succeed the pre-Cambrian with marked unconformity and have a different strike. Wherever an unfaulted junction occurs, their base is marked by a conglomerate of varying coarseness and thickness. Locally the conglomerate contains pebbles of the underlying rocks and vein-quartz reaching several inches in diameter, but occasionally it passes laterally and vertically into a moderately coarse-grained quartzite.

The conglomerate, with attendant quartzite, is succeeded by a series of green, highly micaceous sandstones, about 400 feet thick

which is followed abruptly by 50 feet of red fossiliferous shales. These in turn give way to a series of dull-purple and green sandstones and flaggy shales. The sequence is well displayed on the northern side of the valley between Pen-y-cwm and the sea, and in the neighbourhood of Brawdy. In it is represented the greater part of Hick's Caerfai Series, the uppermost beds of which, however, together with the Solva Series and the Menevian, are not exposed within the district surveyed.

The only other Cambrian sediments recognised are the Lingula Flags which, for the most part, bound the pre-Cambrian mass of Hayscastle, &c., on its northern side, but are separated from it by a line of thrust. They also occur to the east of, and faulted against, the Coal Measures at Roch Bridge and Victoria. They present the same characters as the beds described in last year's Summary from the district to the east.

### ORDOVICIAN.

*Arenig.*—The Tetragraptus Beds have been traced by Mr. Thomas along the southern boundary of the volcanic series of Wolfsdale, from Frog's Hole to the south of Roch Castle, near which place they appear to be faulted out and to give place to higher beds.

*Llanvirn.*—The higher portion of the D. bifidus shales appear as lenticular masses to the south of the Arenig Beds mentioned above. Mr. Thomas has found them only on the southern side of a major east-and-west fault, which, for the greater portion of its length, brings Arenig Beds in contact with Dicranograptus shales. They occur south of Dudwell and south of Roch Castle, while a larger mass outcrops between the St. Davids road and the Coal Measures to the west.

The D. Murchisoni shales have been detected by Mr. Thomas only to the south of Roch Castle, where they succeed the dark shales which mark the summit of the D. bifidus Zone.

*Llandilo.*—Llandilo Flags in the form of decalcified striped flags and shales, occur at Stock Park, south-east of Cuffern, and succeed the Murchisoni shales to the south of Roch Castle. They yield a scanty fauna with the usual Llandilo Flag characters.

Some yellow-weathering ashy flags with *Trinucleus* which emerge from beneath the igneous rocks of St. Ishmaels and Marloes are recognised by Mr. Cantrill as being probably of Llandilo age. The only fossil so far found in them is *Trinucleus concentricus* Eaton var. *favus* Salter.

*Bala.*—Dicranograptus shales were found by Mr. Thomas to occupy a considerable area south of the Tetragraptus and Bifidus shales, from which they are separated by a fault. Southwards, towards Keeston Hill, they pass upwards into Redhill Beds, and south-west of Roch Castle pass beneath the Carboniferous rocks.

Redhill Beds occupy the lower portions of Keeston Hill and are unconformably followed by the Middle Shales of the Millstone Grit.

A re-examination by Mr. Cantrill of the grit-outcrops near Llawhaden shows that a band of conglomerate which contains pebbles of fossiliferous Dicranograptus shale must be referred to

the Redhill and Slade stage of the Bala, and not to the Lower Llandovery as was reported in the Summary of Progress for 1906[1]. In this locality the upper part of the Bala is exceptional in containing several thick grits and conglomerates, some of which are indistinguishable from those at the base of the Lower Llandovery.

### SILURIAN.

*Llandovery.*—A revision of the Llawhaden district by Mr. Cantrill has shown that the basal conglomerate, sandstone and black shales of the Lower Llandovery of Haverfordwest can be traced throughout that district also, and that they overlie conglomerate-bearing mudstones at first thought to be Lower Llandovery, as mentioned above.

The Silurian grits and mudstones of St. Ishmael's are well-exposed in the cliffs of Lindsway Bay. They appear to include beds referable to the Ludlow and Wenlock stages. Still lower beds containing bands of conglomerate emerge around the margin of the igneous rocks and are probably of Upper Llandovery age. These points it is hoped to settle by means of the fossils.

*Wenlock-Ludlow.*—A series of sandy mudstones and shales containing abundant fossils of Wenlock-Ludlow age has been detected by Mr. Jones underlying the Lower Old Red Sandstone from the south of Hasguard towards Slate Mill. The precise determination of the age of these strata awaits the identification of the fossils.

## OLD RED SANDSTONE.

### (1.)—North and East of Milford Haven.

The Old Red Sandstone which bounds the south side of the igneous and Upper Llandovery rocks from Rosemarket to the coast near Talbenny are found by Mr. Jones to consist of red marls with a few bands of grey sandstone and green cavernous marls. The latter are rather prevalent to the west of Walwyn's Castle, probably indicating a low horizon in the Lower Old Red Sandstone. To the north of Benton a thick series of green marls with race and frequent bands of coarse grey sandstone and conglomerate underlies the main mass of the red marls. In the coast-section this Basal Green Series rests, with a few feet of coarse conglomerate at its base, on the Benton rhyolitic rocks.

The softer beds are affected with an irregular cleavage-structure with a steep dip to the south and a prevailing strike of a few degrees north of west.

The Red Marl subdivision of the Old Red Sandstone borders the Haven west of Milford. Mr. Cantrill describes it as consisting of hard red calcareous marls with occasional red and green sandstones. Near its base it contains some thick bands of breccia, chiefly of igneous rocks, vein-quartz and quartzite, best seen at Lindsway Bay, St. Ishmael's, where the green basal beds are absent.

[1] *Mem. Geol. Surv.*, p. 50.

The Cosheston Beds, into which the Red Marls pass upward by alternation to the east of Milford, are a thick group of green flaggy sandstones with some green and red marls. The sandstones yield indeterminable plant-remains. The relations of this group to the Red Marls can be examined in the creek at Neyland and again along a railway-cutting east of Milford.

The existence in this neighbourhood of two distinct green subdivisions, separated by the Red Marls, is thus established.

In the Lawrenny promontory, to which allusion has been made previously, Dr. Strahan has satisfied himself that these two green series are thrown into juxta-position by a large fault. The fault in question has been proved to effect a shift of some thousands of feet near Benton Castle, on the west coast of the Haven, as described on pp. 39, 40. That there was a belt of great smashing on the east coast also was obvious, but it was not clear at first sight how great was its effect, for the following reasons. From the smashed belt northwards the cliff shows in ascending order grey sandstones with numerous bands of marl, some so crowded with calcareous concretions as to constitute cornstones. Bands of quartz-conglomerate also occur. These grey strata are followed by red sandstones and marls, upon which rest the Lower Limestone Shales.

From the same smashed belt southwards also the cliff shows a series of grey sandstones and grits, with subordinate marls. Here, however, there are no calcareous bands while quartz-conglomerates are more gradually developed than on the north side. In spite of these differences it might easily have been supposed that the two green series were one and the same, more especially as those on the south are also succeeded by red strata, followed by the Lower Limestone Shales.

It was, however, not to be believed that the Benton Fault could lose practically all its throw in the quarter of a mile which separates the east and west sides of the Haven. Further examination of the Lawrenny cliff was therefore made by Dr. Strahan in company with Mr. Dixon and Mr. Jones, and the result was to show that the green strata to the north of the fault belong to the Basal Beds and that the actual conglomeratic base is visible at extreme low water close to the fault, where it might be expected; in fact, the Benton rhyolitic rocks upon which this basement-bed rests may occasionally be accessible. The green strata to the south of the fault, on the other hand, belong to the Cosheston Series, which lies above the Red Marls, and some thousands of feet above the Basal Green Beds.

But the Cosheston Beds are succeeded by red strata of no great thickness, and then by Lower Limestone Shales. We arrive, therefore, at the remarkable conclusion that the red strata upon which the shales rest to the south of Lawrenny are some thousands of feet higher than those on which they rest to the north of the village, at only a mile distance. It would be supposed that so rapid an overstep must be accompanied by a conspicuous discordance, but no obvious want of parallelism between the Carboniferous and Old Red strata has been detected. The behaviour of the Benton Fault, however, supplies an explanation. The fault, running past Lawrenny Castle, where it

throws the Red Marls upon which the village is built against the Cosheston Beds, ranges along the margin of the Cresswell River, having nearly vertical Lower Limestone Shale on its southern side, and grey beds with red marl-bands on its northern side. It then should cross the Lower Carboniferous outcrops near Newpark, but it is certain that no such fault here exists. The limestone is sharply folded, and the overlying shales are cleaved in places, but there is no perceptible fracture or displacement of the outcrops. One of two things must have happened; either the fault dies out abruptly eastwards, or it is mainly of pre-Carboniferous age. The latter supposition affords a possible explanation of the fact that the Carboniferous rests on widely different horizons of the Old Red formation without any apparent discordance between the bedding of the two. In connection with the general question of overstep, it may be pointed out that the Old Red is overstepped by the Carboniferous Limestone at Slebech, four miles to the north, and that it does not re-appear along the Carboniferous margin west of that place.

### (2.) South of Milford Haven.

In 1863 it was made known by Salter that marine strata are intercalated in the Old Red Sandstone of West Angle Bay.* He concluded from an examination of their fauna that that part of the Old Red Sandstone in which they occur may be correlated with the Marwood group and the lower part of the Pilton Beds of the Devonian of North Devon. In view of the interest attaching to a correlation of any part of the Old Red Sandstone with the Devonian of the other side of the Channel, Mr. Dixon has devoted much attention to working out the sequence in detail and obtaining fossils from every possible horizon.

He finds that the outcrop of Old Red Sandstone which includes the marine beds is continuous with that at Skrinkle described in previous Summaries and, like it, consists of both Lower and Upper Old Red Sandstone. The latter division, to which the marine horizons are confined, is distinguished, as at Skrinkle, by quartzitic sandstones and breccias, especially in the lower part. The lower of the two marine groups in it commences about 125 feet below what we take to be the top of the Old Red Sandstone, and consists of about 25 feet of grey shales and quartzitic sandstones, with lenticles and bands of limestone. The latter, and the shales also, contain the remains of various marine animals, chiefly lamellibranchs, whereas the sandstones have yielded little except plant-fragments. The group is somewhat conglomeratic at the base and rests sharply on the underlying rock, but is followed by red marls similar to the general mass below. It was deposited, therefore, during a merely temporary marine incursion into an area in which the continental conditions indicated by the Old Red Sandstone still prevailed.

The upper marine group, also, follows a slight break, indicated in this case by borings made by some organism, which penetrate

* *Quart. Journ. Geol. Soc.*, vol. xix, p. 477.

the top of the underlying red marl to a depth of a foot or so. It varies in composition in the lower part and presents several more slight breaks and some contemporaneous erosion, but the most distinctive part is dark-grey shale 5 feet thick, with lenticular limestones, both crowded with marine lamellibranchs. This is followed by some 32 feet of grey beds, consisting of shales, mudstones, and sandstones, in which fossils though still marine are rare or absent. On this group rests a sandstone-band which affords the best horizon at which to delimit the Old Red Sandstone, for above it occurs the most marked step in the gradual change from that formation to the Lower Limestone Shales, and also it appears to be the counterpart of a sandstone on Caldy Island which undoubtedly indicates the close in that area of the chief period of continental conditions. At West Angle Bay, though it is linked with the Carboniferous by yielding brachiopods and crinoids, it resembles the Old Red Sandstone below in its chief constituents, which are sand and well-rounded pebbles of red quartz and partings of red marl.

Comparing this sequence with those exposed in cliffs elsewhere in Pembrokeshire along the same outcrop we find that at Skrinkle the short marine phase near the top of the Old Red Sandstone* is totally different in rocks, fossils and extent, whereas the corresponding strata on the west coast of Caldy, though farther from West Angle Bay, are less unlike the development at that place. On the east coast, however, of the island, no such episode whatever is evidenced.

Thus it appears that in the area under consideration the open-sea conditions prevalent during the Lower Carboniferous period have been foreshadowed by temporary approaches to such conditions towards the close of the Old Red Sandstone.

## CARBONIFEROUS.

### *Carboniferous Limestone Series.*

Much interest attaches, also, to that part of the Lower Limestone Shales which immediately follows the Old Red Sandstone at West Angle. As it consists partly of ostracod-limestones and shales with lamellibranchs it evidently belongs to the Modiola-phase of the Cleistopora Zone.† In its lithological sequence, in which it is closely parallel to the Skrinkle development, the most notable feature is a group of red limestones, about 11 feet in all, characterised by well-rounded pebbles of red quartz and, more particularly, by numerous bryozoa and crinoid ossicles, which have been reddened by hematite at the period of their deposition. In this peculiarity they resemble limestones on approximately the same horizon at various places in South Wales and the Bristol district, the resemblance to the "Bryozoa-Beds" (horizon *a* of Vaughan, *loc. cit.*) of the Avon Gorge being remarkably close.

At West Angle Bay they are separated from the top of the Old Red, previously defined, by about 50 feet of shales and limestones of Lower Limestone Shale type, but show affinities with

* 'Summary of Progress' for 1904 (*Mem. Geol. Surv.*), 1905, p. 42.
† Dr. A. Vaughan, *Quart. Journ. Geol. Soc.* vol. lxi, 1905, p. 188.

the Old Red in the inclusion of pebbles of red quartz and in their colour, the latter feature, as we have seen, generally distinguishing their horizon elsewhere also. We may, therefore, regard these peculiarities as due to a wide-spread, though brief, reversion to continental conditions, and we may even suppose, in view of the variability of the uppermost Old Red strata, between marine and continental conditions, that in some adjoining area deposition of Old Red Sandstone may have persisted continuously up to the period of the red limestones of West Angle Bay.

### MILLSTONE GRIT.

*The Middle Shales and Farewell Rock.*—So far as regards the northern part of the district, Mr. Thomas finds that dark shales and mudstones, with striped sandy shales and sandstones, form the summit of Keeston Hill and pass in a north-westerly direction towards Hilton and south-westerly towards Simpson. They are well exposed in Cwm Mawr, Newgale, where they are thrown into contact with the purple sandstones of the Lower Cambrian.

The Farewell Rock, a coarse and often conglomeratic felspathic sandstone, succeeds the Middle Shales at Newgale. It extends north-eastward towards Pen-y-cwm and, as a very friable rock, forms a ridge running from near Eweston to Pignog.

### COAL MEASURES.

Coal Measures, striking approximately east and west, have been mapped by Mr. Thomas on the north and south of Newgale Marsh. The lowest coals, on the north of the marsh, are associated with thin sandstones. To the south, between the marsh and the St. David's road, a thick shale-series is met with, which contains some of the more important coals of the district. Further south towards Bathesland, still higher beds occur, containing numerous sandstones and a few good seams of coal. South of Bathesland, the strike of the rocks changes suddenly from east and west to north and south and follows the coast towards Nolton Haven. Sandstones are prevalent between the higher, more westerly, seams which appear to be on about the same horizon as, or higher than, those occurring to the immediate south of the St. David's road.

The roofs of the higher seams yield abundant plant-remains. All the coal exists in the form of anthracite.

The part of the coalfield which extends from the Eastern Cleddau to St. Bride's Bay has been examined by Mr. Jones. The lower beds of the Coal Measures form the southern part of the promontory included between the Eastern and the Western Cleddau. They contain some coal-seams which have been worked near the crop only. The highest measures on Picton Point contain a large proportion of black shales and poor fireclay with irregular concretions of mine; they probably lie not far below the Timber Vein which comes in further to the south. About half a mile up the Western Cleddau from Picton Point a marine fauna, consisting of a few species as yet undetermined,

was found in blue-black shales with some calcareous nodules. These beds are below those at Picton Point, but must be some distance above the base of the Coal Measures.

The Timber Vein is the principal vein of Hook and Freystrop, and has been largely worked in those districts. The veins in ascending order which overlie it are the Low, Tumbling, and Rock, each of which has been worked in a few places. The main outcrop of the Timber Vein can be traced almost continuously along the south side of the Western Cleddau, north of Hook and thence as far as Little Cranham, three-quarters of a mile west of Freystrop Cross. Beyond that point it has not been recognised with certainty though it is probable that the deep trench-like workings of Coalpit Park north of Johnston were on that vein and those associated with it.

In the Hook district, besides the main outcrop there is a belt of ground ranging westwards from the west end of Sprinkle Pill where the Timber Vein outcrops in places, and in others is rolled up near the surface along an anticlinal axis.

This district is crossed by several important faults with a downthrow to the north, which have been proved in the workings. These cut up the Timber Vein ground into belts, in the deeper parts of which the Rock Vein and those underlying it occur. To the south of all the Timber-Rock Vein workings is a tract of ground consisting of measures, chiefly barren, but occasionally containing a thin seam of coal, while to the south of these lies a broad stretch of Millstone Grit shales and sandstones seen along the Daucleddau north of Blacktar. The boundary between them and the barren Coal Measures is probably a fault.

From Jornston westwards nearly to the coast the Coal Measures occupy a belt of variable width between the Farewell Rock which underlies them on the north and the older rocks which had been thrust over them on the south. From the fact that but little coal has been worked in this tract it is probable that only the measures below the Timber Vein are represented there, a supposition in agreement with the lithological character of the rocks, which contain frequent sandstones of a type characteristic of the lower part of the Coal Measures of the district. We may suppose therefore that a comparatively small thickness of rocks is made to occupy a considerable area by the operation of folds and overthrust faults.

There is abundant evidence near Broad Haven and Little Haven that this is true as regards the coastal region, for the Coal Measures there are greatly folded and overthrust from a southerly direction. From the range of the structures it is fairly certain that similar conditions prevail inland.

### FAULTS AND DISTURBANCES.

The chief disturbances recognised by Mr. Thomas in the Ordovician and Cambrian rocks to the north of the coal-field are those which range a little north of east to south of west. The most northerly is a thrust which from Pointz Castle eastward brings Lingula Flags over from the north on to the Cambrian and pre-Cambrian rocks.

To the south, a more or less parallel disturbance throws the Cambrian strata into contact with the Millstone Grit, and continues, along a well-marked fault-valley, through the pre-Cambrian rocks towards Hayscastle.

Other parallel faults bound the rhyolitic rocks of Plumstone and Roch, and throw the Bifidus and Tetragraptus Beds against the Dicranograptus Shales.

In the Hook district several important faults with a downthrow to the north have been found by Mr. Jones to traverse the coal-field in a direction nearly east and west. They are of the nature of overthrusts from the south, and may form part of the disturbances met with in the Landshipping district on the opposite side of the river, which have a similar range and direction of throw.

The over-thrust fault which bounds the Carboniferous tract on the south pursues a peculiarly sinuous course from Langum to the coast north of Talbenny, though its general direction a little north of west is fairly straight. Its outcrop is indicated on the Old Series geological map by the northern margin of the mass coloured as greenstone and syenite, but the sinuosities are actually more pronounced than is there shown. An outcrop of this kind would be produced if an overthrust with a low inclination crossed a tract of sensible relief. In the present case, however, the surface-features are so subdued that the sinuosities could only result from the overthrust being almost horizontal; but as there is some evidence that the inclination of the plane is not very low, and as abrupt changes in direction of the outcrop occur which are independent of the form of the ground, it follows that the sinuous course is due in a large measure to undulation of its plane along north-and-south axes, though the general dip is towards the south. It is not believed that such undulation has been produced by folding of later date than the main movement which gave rise to the overthrust.

The Carboniferous rocks in front of the overthrust are much disturbed in places, and near Johnston intensely-sheared Carboniferous Limestone has been brought up in faulted lenticles among the Millstone Grit rocks.

Near the foot of the sea-cliff in Goultrop Roads, near Talbenny, there is, as observed by De la Beche, a remarkable section, which shows Carboniferous Limestone in massive form and in lenticles which are set in a matrix of sheared black shale, the whole being overlain by considerably sheared dioritic rocks which occupy the upper part of the cliff and extend for about half a mile to the south. The plane of the overthrust is actually visible at one point and there appears to be almost horizontal, but on the other hand the course of the overthrust along the cliff-face to the east indicates a considerable inclination of its plane.

Another important fault lies to the south of the above. It ranges from the Daucleddau near Benton and Lawrenny to the coast near Mill Haven, west of Talbenny, and throws different horizons of the Lower Old Red Sandstone on the south against various older rocks on the north. There is reason to believe that the sandstones and conglomerates exposed in the banks of the river on the south side of the fault near Benton are high in the

Cosheston Series, which itself, though forming part of the Lower Old Red Sandstone, lies above the great mass of the Red Marls of the district. Although it is not possible at present to calculate the combined thickness of the Red Marls and the Cosheston Series it is certainly some thousands of feet. Immediately on the north of the fault are the Benton rhyolitic rocks and the lowest beds of the Old Red Sandstone which rest unconformably on them. It seems therefore impossible to escape the conclusion that the throw of the fault at this point must be very large indeed. It is a remarkable fact to which reference has already been made on p. 40, that although this fault ranges for the basal beds of the Carboniferous Limestone Series near Lawrenny no displacement of comparable size has been detected in those beds.

From Benton this great dislocation pursues a fairly steady west-north-westerly course to the coast some 12 miles away. It is clearly shown in the cove known as Foxes Holes, where from the intense amount of shearing which accompanies it, and from the character of the fracturing visible on the plane of movement, it can be seen to have been an overthrust from the south. Its effect, however, has been to push newer rocks (Old Red Sandstone) over much older dioritic rocks, and not as is usual with overthrusts, an older over a newer rock. The inclination of the thrust-plane is about 30° to the south.

Another important fault with approximately the same range has been proved by Mr. Cantrill to separate the Silurian and igneous rocks of St. Ishmael's from Old Red Sandstone on the north.

The broad anticlinal fold with east-south-easterly pitch which carries the Carboniferous Limestone outcrop round the Old Red Sandstone area of Lawrenny and Cosheston is revealed farther west by the course of the base of the Cosheston Beds at Neyland.

Many small anticlines and synclines are exposed along the north coast of Milford Haven. They range a little north or south of west; and as the southern limbs of the anticlines often dip more steeply than the northern, they seem to imply movement from the north.

### GLACIAL.

Little true boulder-clay is met with, but sands and gravel cap many of the minor elevations. Isolated boulders, indicative of a westerly or north-westerly source, are of frequent occurrence.

Skomer and Midland Is. were found by Mr. Thomas to be almost completely covered by a level deposit of sandy loam and gravel, from which crags of rock stand out as islands.

Mr. Jones finds boulder-clay in force near Talbenny, although for several miles to the east of this the country has proved to be almost free from drift. It contains numerous igneous boulders among which quartz-porphyries and a coarse felsite-breccia or conglomerate are the most abundant constituents. A boulder of the latter, several tons in weight, occurs on the edge of the sea-cliff west of Talbenny.

Scattered boulders and small patches of gravel and boulder-clay have been met with by Mr. Cantrill on the plateau between

Neyland and St. Ishmael's, but west of Dale inlet these materials appear in force and cover most of the Dale peninsula. The included pebbles indicate a northerly and north-westerly derivation.

RAISED BEACH.

Traces of the Raised Beach have been detected by Mr. Cantrill at various points along the northern shore of Milford Haven, the deposits consisting of a thin bed of loamy gravel at high-water mark, underlying 'head,' and resting on a rock-platform.

The streamless valley which runs across the peninsula from East to West Dale appears to be choked with 'head' and may possibly have been a sea-channel in pre-Glacial times.

## II.—PETROGRAPHICAL DEPARTMENT.

During 1908 four sheet-memoirs have received contributions from Dr. Flett, viz.:— St. Austell (Cornwall, Sheet 347), Glen Tilt (Sheet 64), Tayvallich (Sheet 28), and Garve, Ross-shire (Sheet 93). Dr. Teall has been engaged in a study of the rocks of the Ivybridge sheet (Cornwall, 349), and in other districts some of the geologists have undertaken the investigation of the whole or part of the rocks sliced from the area which they have themselves mapped. In this way a very large number of rocks has been examined during the course of the year, and to give an account of the results obtained would far exceed the limits of the space at our disposal. Only a few of the more salient points of interest met with can be mentioned here.

*Felspathic Hornstones from the Aureole of the St. Austell Granite.*—Along a narrow belt of country which extends eastwards from Newquay to Bodmin,* the Meadfoot beds of the Lower Devonian in Cornwall consist of alternations of fine silts, argillaceous limestones, and shales. In the western part of their outcrop these rocks have been greatly sheared and are converted into slates and phyllites, which consist of muscovite, chlorite, and quartz. In microscopic sections they show cleavage and slip-cleavage in great perfection, but the clastic structure of the more sandy beds is not obliterated, and in the limestones recognisable fragments of crinoids are often visble. About St. Columb Major these rocks enter the district which has been affected by the contact action and pneumatolytic changes produced by the St. Austell granite, and they undergo a metamorphism which is both rapid and complete. The gritty and argillaceous bands are but little affected, though sometimes they are slightly indurated and in microscopic slides the presence of new brown biotite can be detected. The impure limestones, however, assume the character of hornstones, and are rich in calc silicates, of which the most frequent are pale augite (diopside), bright yellow epidote, green actinolite and sphene, while some bands are full of zoisite and others consist mainly of brown or yellow anisotropic garnets.† These calc silicate hornstones have often been

* 'The Geology of the Country near Newquay' (*Mem. Geol. Surv.*), 1906, p. 14.
† G. Barrow, in the 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), p. 32.

impregnated with boric acid discharged from the granite during its consolidation, and masses of *limurite* (axinite-epidote-pyroxene rock) are common in the quarries and strewn along the fields.* They present the closest similarity to the limurites of the Pyrenees which have been described by Zirkel† and by Lacroix.‡ Masses of limurite have long been known to occur in Cornwall and Devon, principally in the greenstones which are in the vicinity of the granite,§ but in the country which lies to the west of Bodmin, as Mr. Barrow has shown, they attain an extraordinary development.

The limurites often occur as veins which cross the bedding or run along it for short distances; they have usually a purple-brown colour from the abundance of axinite and they are exceedingly tough and hard to break. The altered Meadfoot beds show great variations of colour. The slaty bands are black and glossy when they contain biotite, the calc silicate hornstones are yellow or greenish according to the prevalence of epidote or diopside and actinolite. Alternating with these are white, pale-grey, or green bands, which have very much of the appearance of cherts, and for this reason Mr. Barrow has described them as "calc-flintas." They have a sub-conchoidal fracture, are slightly transparent at the edges of thin chips, are very splintery, and weather with a thin white crust. If tested before the blowpipe, however, they are distinctly fusible, and when they are examined under the microscope they prove to consist in large measure of fresh, water-clear alkali felspar. This mineral has a lower refringence than quartz and Canada balsam, and is in consequence easily distinguished from the other constituents of the rock.

A section of one of these felspathic hornstones usually shows a multitude of small rounded grains of quartz which were originally sand-grains in a somewhat arenaceous silt. By shearing they are often flattened out to lenticular forms, but the clastic structures are probably never completely destroyed by recrystallization. The matrix is exceedingly fine-grained and might in some cases be described as cryptocrystalline; it consists of felspar and quartz, perfectly transparent and without traces of regular crystalline forms. Small veins and nests of quartz and albite are found in many of the rocks, and in these the minerals are more easily identified. Radiate bunches of fibrous actinolite, small yellow prisms of epidote or zoisite, and irregular grains of diopside are rarely absent though often they are restricted in their occurrence to certain bands which were originally calcareous laminæ of deposit, and to veins which may cross the bedding abruptly.

The genesis of these felspathic hornstones, and in particular the source of the new felspar is a problem of some interest. We know that enormous quantities of alkalies must have been liberated from the felspars of the St. Austell granite during the process of kaolinisation; for every ton of kaolin in the altered

* G. Barrow and H. H. Thomas. *Mineralogical Magazine*, vol. xv (1908), p. 113.
† F. Zirkel, *Neues. Jahrb. für Mineralogie*, 1879, p. 379.
‡ A. Lacroix, La Granite des Pyrenées, *Bull. Carte. Géol. France*, vol. xi (1900), p. 58.
§ J. S. Flett, in the 'Summary of Progress' for 1903 (*Mem. Geol. Surv.*), p. 152.

granite about six hundredweights of potash and soda must somehow have been carried away in solution. It is strange that no evidence can be found in Cornwall of infusion of alkalies in the rocks around the granite; possibly the alkaline solutions were at too low a temperature to effect combination with the minerals of the killas. At any rate, these felspathic hornstones can hardly be believed to have absorbed alkalies since by analysis they are proved to contain no more of these substances than the unaltered killas.*

In the less altered phyllites the alumina and alkalies exist in combination in the white mica; and many of these phyllites are exceedingly rich in fine muscovite or sericite. In the typical felspathic hornstones, however, the mica has disappeared and felspar takes its place; it is unnecessary to point out that mica is far more aluminous than felspar. Hence the microscopic evidence favours the view that there has been an abstraction of superfluous alumina. It has been used to form lime-alumina silicates, such as axinite and epidote, in the veins.

In external appearance, in microscopic character, and in mineral composition these hornstones have an exceedingly close resemblance to the adinoles. The latter are found mainly where diabase sills have altered shaly sediments, and very fine examples of them are known at Dinas Head, which have been described by Mr. Fox and Dr. Teall.† We have not called these rocks adinoles, however, because, so far as is at present known, they show certain distinctive features which are not observed in adinoles. Chemical analysis shows that the adinoles contain much more alkalies and alumina; many of them must have 70 per cent. of felspar; the original rocks were more argillaceous or shaly, while the felspathic hornstones were derived from fine argillaceous sandstones. The hornstones also contain more lime than the adinoles.

For analogies to the calc-flintas of the Bodmin and Columb area we must look to regions where argillaceous limestones and sandstones have been thermally altered by granite masses. Splendid instances of this occur in the Pyrenees and among the "cornéens verts rubannées" or banded green hornstones which Lacroix has described from that area‡ there are not a few which contain new felspar, though it is not always albite as in the Cornish rocks. A still closer parallel is afforded by the greenish, cherty-looking rocks which resemble adinoles and have been described by Weed and Pirsson from the contact aureoles of the Crazy Mountains, the Castle Mountain District, and Highwood Peak in Montana.§ These are found in calcareous beds like those of the Meadfoot Series, and in all probability in them also the tendency for the lime to combine with alumina and silica has led to the development of authigenic felspar at the expense of original white mica.

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* Analyses of some of these rocks will be given in the St. Austell memoir, shortly to be published.

† *Geological Magazine*, 1895, p. 13.

‡ A. Lacroix, *loc. cit.*

§ Weed and Pirsson, Igneous Rocks of Highwood Mountains. *Bull. U. S. Geol. Surv.* No. 237 (1905), p. 24.

*Tourmaline-albite Rocks.*—In the same district and often associated with these hornstones there are fine banded rocks which consist of tourmaline and clear albite, a combination which has not hitherto been described from Cornwall. It is well known that the killas or clay-slates of Cornwall are very commonly altered to quartz-tourmaline rocks, especially in the vicinity of fissures which have served as vents for the gases which were emitted by the granite when it cooled. In these rocks, though there has been almost complete replacement of the original minerals by quartz and tourmaline, the banding (which is often bedding), the cleavage, and even the slip-cleavage of the slates are very perfectly retained. This is also the case in the tourmaline-albite rocks, a fact which is important as proving that these are altered shales. The tourmaline forms matted clusters of slender prisms; the albite is a mosaic of minute irregular grains. Some of these rocks contain practically no quartz. As authigenic felspar is uncommon in the altered rocks of the aureoles of the Cornish granites, except in the felspathic hornstones, we may reasonably conclude that the tourmaline-albite rocks are representatives of the hornstones which have experienced pneumatolytic change by the boric and fluoric vapours derived from the granite.

*Nepheline Rocks from Scotland.*—During the revision of the Scottish coalfields which is at present in hand, opportunity has been taken to examine afresh the volcanic rocks which attain so large development in the Midland Valley of Scotland; this work is being done conjointly by Dr. Flett and Mr. E. B. Bailey, and the latter has met with some interesting nepheline-bearing rocks of basic composition. These form an important addition to a group which is not abundantly represented in Britain. The only basic rock containing nepheline which has hitherto been met with in Scotland is the Crawfordjohn dolerite, very well known and much used for making curling-stones, which Professor Lacroix showed several years ago to be a nepheline-teschenite* The resemblance of this rock to the Lennoxtown essexite, both in hand-specimens and under the microscope is extraordinary, although one of these is Carboniferous and the other is believed to belong to a series of Tertiary intrusions.

At Barshaw, not far from Paisley, there is a large quarry yielding a dark-coloured, rather coarse-grained rock, which proves to be a weathered *theralite*. It occurs as a sill, apparently in close association with the Paisley teschenite, although the two are not actually seen together. It will be remembered that the picrites of the Central Valley of Scotland are always most intimately connected with teschenite intrusions and there is undoubtedly a close resemblance between the Barshaw theralite and these picrites, especially the Ardrossan hornblende-picrite described by Dr. Falconer.†

In the hand-specimen the theralite is a dark rock of doleritic aspect; under the microscope it presents a striking appearance.

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* A. Lacroix. *Comptes Rendus*, cxxx (1900), p. 1273.
† J. D. Falconer, *Trans. Roy. Soc. Edin.*, vol. xlv (1907), p. 605.

It mostly consists of purple zonal augite and dark-brown hornblende in nearly equal proportions. The hornblende has, as usual, grown about the augite, but externally it shows its proper crystal form. Olivine is more sparingly represented by well-formed pseudomorphs in sepentine. Iron-ores are scarce and small: biotite is absent, apatite fairly abundant. There is a little basic labradorite present, but most of the interstitial material consists of secondary products, chlorite, and cloudy analcite. One slide (12,873) shows that the latter is, in part at least, derived from the decomposition of large allotriomorphic plates of nepheline, kernels of which are still preserved.

The Lennoxtown *essexite* occurs as a massive dyke, 700 yards long by 100 yards broad, intruded into the Campsie volcanic plateau. It is well exposed by the side of the Craw Road, a mile north of Lennoxtown. In the hand-specimens it represents the appearance of a fine-grained gabbro or coarse dolerite, frequently containing large porphyritic crystals of augite. In these characters it exactly resembles the nepheline-teschenite of Crawfordjohn and the essexite of Brandberget, Christiania.* Under the microscope (13,311) its resemblance to these rocks is equally striking, and it has in fact been placed in the essexite group on account of its very close similarity to the well-known Christiania rocks. Purple augite, olivine, and basic plagioclase felspar, in nearly equal proportions, make up the bulk of the rock. Flakes of red-brown biotite, big grains of titaniferous magnetite, long needles of apatite and interstitial patches of analcite are also conspicuous, while orthoclase and nepheline can be found on careful examination. The nepheline occurs in large crystals, much cut up by the lath-shaped sections of plagioclase. It is eumorphic to the later original analcite and occasionally also to the felspars. The Crawfordjohn rock carries less olivine and analcite, but is otherwise practically identical with the rock under description.

The Cathcart *nepheline teschenite* (13,650) occurs in a group of sills near Cathcart Castle, Renfrewshire. The resemblance between this rock and the Lennoxtown essexite is so close that a detailed description is unnecessary. It is, however, of finer texture and poorer in olivine, while analcite and biotite occur more plentifully than is at all usual in the Lennoxtown rock. Hornblende has been noted in fair quantity in a few specimens, as has been remarked by Mr. Macnair,† but this is an unusual feature.

The mineral described as nepheline has in all respects the physical properties of nepheline, except that Mr. Bailey has found its refractive index to be slightly lower than that of the nepheline which is usual in Tertiary and recent rocks. This property characterises also the nepheline of the Crawfordjohn rock described by Professor Lacroix. The same mineral occurs also in the "limburgite" of Chester's quarry, Haddingtonshire, which was described by Dr. Hatch,‡ and a similar rock from the

* H. Rosenbusch, *Mikroskopische Physiographie*, B. ii, pt. 1 (1907) p. 404.

† P. Macnair, *Trans. Geol. Soc. Glasgow*, vol. xiii (1907), p. 30.

‡ F. H. Hatch, *Trans. Roy. Soc. Edin.*, vol. xxxvii (1892), p. 123.

Fuller descriptions with chemical analyses of these rocks will appear in the Geological Survey Memoirs on East Lothian and on the Glasgow District.

Limplum, also in East Lothian. These must consequently be classified with the *nepheline basalts*. Professor Rosenbusch has noted the occurrence of nepheline in the limburgite of Chester's Quarry (Whitelaw Hill).*

## III.—PALÆONTOLOGICAL WORK.

The large number of fossils collected during the year in connection with the current work of geological mapping have been dealt with principally by Dr. Ivor Thomas, but many specimens from the Survey and Museum collections have also been submitted to the following specialists who are not members of the staff:—Mr. S. S. Buckman, Dr. Wheelton Hind, Dr. G. J. Hinde, Dr. R. Kidston, Mr. P. Lake, Dr. C. A. Matley, Mrs. Shakespear, Dr. R. H. Traquair, and Dr. A. Vaughan. The information brought together in the various reports on the Survey specimens will be utilised in the respective sheet-memoirs, and there are few special points of scientific interest arising in connection with recently-collected materials, to which it is necessary to draw attention here.

It may be mentioned that Dr. Thomas has recognised some new species among the specimens of Upper Devonian age, collected by Mr. Clement Reid at Port Quin in Cornwall, and his descriptions of two of these, a trilobite and a lamellibranch, have already been communicated to the "Geological Magazine." The goniatite-fauna of this particular locality is an interesting one and comprises forms, such as *Cheiloceras*, and species of *Tornoceras*, which enables us to make comparison with the fauna of the Cheiloceras Horizon so widely distributed on the Continent. The English Upper Devonian fauna includes other new trilobites, some of which it is hoped will also be described by Dr. Thomas, and the Devonian Cephalopoda collected in early and recent years by the Geological Survey also call for detailed study in the near future. A point of some interest is the occurrence of certain cephalopods in the Upper Devonian rocks of Trevone Bay, which seem to be most closely comparable with species characteristic of the Middle Devonian Wissenbacher Schiefer of Germany.

Dr. Thomas has made considerable progress with a detailed study of the Carboniferous Productids, and, so far, his work on this subject has been chiefly confined to the examination of types and figured specimens. In this connection he has made frequent visits to the Geological Department at the British Museum (Natural History), where the necessary facilities have been kindly granted to him. It has become clear that Davidson and de Koninck set such wide limits to many species that the results of their work do not permit of immediate application to zonal stratigraphy and palæontology, and critical revision, with due recognition of zonal occurrence, becomes necessary. For instance, *Productus semireticulatus* of Davidson includes forms which are distributed through the Carboniferous Limestone Series from the horizons Z to $D^1$, inclusive. It will no doubt be found practicable to recognise within this broadly-defined species several

* H. Rosenbusch, Mikroskopische Physiographie II., p. 1472, (1908).

forms which may be of use in characterising zonal sub-divisions, and the same remark applies to other broadly-conceived species as defined by the earlier writers. As a further aid in carrying on this work, Dr. Thomas visited sections in the Carboniferous Limestone in Pembrokeshire and Carmarthenshire, where he collected specimens of *Productus* and made observations relating to zonal distribution.

Dr. Kitchin spent a considerable time in re-examining the Mesozoic fossils obtained a few years ago from the colliery-sinkings at Dover and from the deep borings at Brabourne and Penshurst in Kent, in preparation for a memoir to which he is contributing in collaboration with Mr. G. W. Lamplugh. Among the more interesting points which have resulted from a comparison of the fossils from these three sections may be mentioned the evidence for striking variation in the development of the Kimeridgian Series. At Dover, where there is a sharp unconformity between the Cretaceous and Jurassic strata, the Hastings Beds rest directly upon an irregular surface of Kimeridge Clay, and the clay itself is shown to be referable to the beds with *Exogyra virgula* (Defr.) low down in the Kimeridge Series. It is highly probable, from the palæontological evidence alone, that the denudation which removed the Kimeridge strata of post-virgulian age also swept away part of the Virgula Beds in this locality.

Passing westward to Brabourne, we find the *Exogyra virgula* Beds completely represented and overlain by an upper series of clays. While *Exogyra virgula* and *Gervillia kimmeridgensis* (d'Orb.) are leading fossils in the Virgula Beds, these species and some of their associates were not met with in the overlying series, which is characterised in turn by *Modiola autissiodorensis* (Cott.) and certain associated lamellibranchs, and by species of *Perisphinctes* (some showing polyplocoid degeneration) and of *Holcostephanus* [*sensu latissimo*]. Even though the upward passage into the Portlandian Series may perhaps be not quite unbroken at this locality, it is probable that no substantial break occurs at the top of the Upper Kimeridge Clays, which are here about 70 feet thick. Still further westwards, at Penshurst, where there is an unbroken sequence from the Kimeridge to the Portland Series, the Kimeridge Clay is upwards of 600 feet thick. A study of the fossils yielded by the cores leads us to believe that the *Exogyra virgula* Beds were never reached in this boring, but that a remarkable thickening of the upper clays had taken place in this area. Not only were the characteristic fossils of the *Exogyra virgula* Beds not met with in the lowest cores, but *Modiola autissiodorensis*, which is confined to the upper clays at Brabourne and is absent from the Virgula Beds both there and at Dover, was present at Penshurst down to the base of the boring.

Many fossils were obtained from the Oxford Clay Series at Dover, and the presence of the Cordatus Zone at the top, with forms of *Cardioceras*, and the Ornatus Zone at the bottom, with species of *Cosmoceras*, could be readily inferred. It was seen

that, amongst other ammonites, species of *Quenstedtoceras* occurred below the Cordatus Beds. The remains of Jurassic ammonites obtained from these Kentish sections have been recently submitted to Mr. S. S. Buckman, whose special knowledge of these forms and of their zonal distribution enables the best use to be made of the specimens, many of which are fragmentary or obscure in character. From the Cordatus Zone Mr. Buckman recognises *Cardioceras quadratum* (J. Sow.), *C. maltonense* (Young and Bird), and *C.* cf. *cordatum* (J. Sow.), and he names several species of *Quenstedtoceras* from the underlying beds, including *Q. mariæ* (d'Orb.) and *Q. lamberti* (J. Sow.). At a lower level again there are species, such as *Creniceras crenatum* (Brug.), from which he infers the presence of the Zone of *Creniceras renggeri*, in the comparison with continental occurrences.

As regards cephalopod-remains, the oolitic series between the Oxford Clay and the Lias, both at Dover and Brabourne, has proved singularly barren, but the Upper Lias at both localities has yielded determinable ammonites. From the uppermost bed of the Lias at Dover Mr. Buckman has recognised *Dactylioceras delicatum* (Simp.) and *D. annulatum*? (J. Sow.), which fall within or just below his Falcifer Zone. At Brabourne, beds of later Toarcian age are attested by *Dactylioceras commune*? (J. Sow.), *Hildoceras walcotti* (J. Sow.), and *Grammoceras* cf. *striatulum* (J. de C. Sow.). Although the evidence of ammonites was not obtained, there is reason to believe that the Middle Lias is represented without a break in the series both at Dover and Brabourne. Some portion of the Lower Lias is also present, but the lowest bed at Dover, resting directly upon Coal Measures, has yielded *Liparoceras maculatum* (Young and Bird), indicating that nothing older than the Capricornus Zone is represented. Mr. Buckman believes that at Brabourne, in addition to species of that age, there is evidence for the presence of the underlying Jamesoni Zone. The lowest 20 feet of Lias strata in this core yielded no ammonites, and there is doubt concerning the zone to which the bottom beds should be assigned; but the Rhætic Beds are absent, and the base of the Lias rests directly upon red and mottled Triassic marls.

Among the many specimens which have been submitted to Mr. Allen for determination during the year, some fragments from the deep borings at Cliffe, Kent, were of exceptional interest, since they proved to be of Silurian age. Though the fossils were very scanty and imperfectly preserved, Mr. Allen was able to recognise *Atrypa reticularis* (Linn.) and *Plectambonites sp.* in this rock from a depth of 1,063 ft., underlying strata of Lower Cretaceous age. The absence of Coal Measures at that spot was thus determined. These interesting specimens have been kindly presented to the Geological Survey by Mr. Baldwin Latham.

In the Museum Mr. Allen has continued to utilise a special case for the reception of recent additions to the palæontological galleries, and a series of Carboniferous corals has there been displayed to illustrate the recent work by Mr. R. G. Carruthers on

the development of *Caninia*. A few sponges of Senonian age from Flamborough, showing an exceptionally good state of preservation of the outward features, have also been placed in this case. In addition to other curatorial work carried on by Mr. Allen, satisfactory progress has been made by Mr. S. W. Morgan in adding to the register of fossils, and a much-needed revision of the naming of Liassic ammonites has been partly carried out by Mr. S. S. Buckman, and is still in progress. Dr. Wheelton Hind is utilising specimens from the museum in his present study of the Silurian lamellibranchs, and some of his revisions of nomenclature have already been carried into effect on the museum labels.

Mr. J. Pringle twice visited the new railway-cuttings in the neighbourhood of Bicester, and the second time he was assisted by Mr. J. Muir. The sections examined extended from the Ampthill Clay downwards through the Oolitic rocks to the Middle Lias. A good series of specimens was secured, accurately located in the sections, and they should prove useful for the purpose of comparison.

In November Mr. Pringle visited Templecombe, Somersetshire, and collected specimens from cores brought up from a boring near Stowell; facilities for this work were kindly given by Mr. W. Phelps, C.E. Fossils were obtained from the Upper Fullers Earth Clay, the Fullers Earth Rock, and the Lower Fullers Earth Clay. An account of the boring is published in Appendix I.

The following specimens in the Museum have been described or figured and described during the year:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1908.

*British Graptolites*, Part 7.

By MISS ELLES, Sc.D., and MISS WOOD, D.Sc.

Trigonograptus ensiformis (*Hall*), pl. xxxv, f. 1*b*, and text-figure 202*b*, p. 302.

*British Cambrian Trilobites*, Part 3.

By MR. PHILIP LAKE, M.A.

Olenus micrurus *Salter*, pl. v, figs. 11, 12, p. 55.
„ cataractes *Salter*, pl. v, figs. 13, 14, 16, 17, p. 56.

*Cretaceous Lamellibranchia of England*, Vol. II., Part 5.

By MR. HENRY WOODS, M.A.

Cyprimeria (Cyclorisma) rotomagensis (*d'Orb.*), pl. xxix, figs. 4, 5, p. 186.
„ „ faba (*J. de C. Sow.*), pl. xxix, f. 11, p. 187.
Clementia (Flaventia) ovalis (*J. de C. Sow.*), pl. xxix, figs. 20, 26, p. 191.
Cardium sp., pl. xxxii, f. 12*a*, *b*, p. 204.
Toucasia lonsdalei (*J. de C. Sow.*), pl. xxxiii, figs. 4, 5, p. 207.
Corbula gaultina *Pict. and Camp.*, pl. xxxiv, figs. 15, 16, p. 214.
„ sp., pl. xxxiv, f. 13, p. 213.

In the Geological Magazine, Vol. V., 1908.

By Dr. F. A. Bather, M.A., D.Sc.

Lebetodiscus dicksoni (*Billings*), pl. v., text-figures 1–4, p. 543.

By Mr. R. G. Carruthers.

Caninia cornucopiae *Mich.*, pl. vi., f. 1, 1*b–k*, text-figures E, figs. 1, 2, 3, 6; F, fig. 3, p. 158.

In the Centralblatt für Mineralogie, Jahrg. 1908, No. 14, Stuttgart.

By F. Frh. von Huene.

Oxyodon britannicus *sp. nov*, text-figure 1, pp. 431–434.

## IV.—MUSEUM OF PRACTICAL GEOLOGY.

In co-operation with members of the field-staff temporary exhibits have been arranged to illustrate the memoirs on the Plymouth, Mevagissey and Land's End districts.

The only other change of general interest completed during the year has been the removal of the mineral cases from the hall to the first floor: all the mineral collections are thus placed in the same room.

# II.—SCOTLAND.

## I.—FIELD-WORK.

The ground surveyed in the Highlands was arranged in two districts as follows:—

1. West Highland district, including the area in the neighbourhood of Glencoe and Ben Nevis, with part of Mull, under Mr. Clough, M.A.

2. North and Central Highland district, containing parts of the counties of Caithness, Perth, Inverness and Argyll, under Mr. Hinxman, B.A.

In the West Highland district all the mountainous ground left unsurveyed at the end of 1907 in Sheet 53 was finished, and that sheet is now completed. Field work was continued in Mull in Sheet 44.

In the Caithness portion of the North and Central Highland district field work was continued in Sheets 109 and 110, and the latter sheet was finished. In the Central Highland district mapping was resumed on either side of the Moor of Rannoch in Sheet 54.

In the coalfield areas the revision was carried on in the northern part of sheet 31, from Longriggend and Cumbernauld eastwards by Falkirk and Slamannan to the Carron coalfield, and in the southern portion of that sheet, from Chapelhall eastwards by Shotts towards Fauldhouse.

### I.—West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A.,
Mr. H. B. Muff, B.A.,
Mr. E. B. Bailey, B.A.,
Mr. T. O. Bosworth, B.A., B.Sc., } Geologists.

The work was carried on in the one-inch maps 43, 44, 53, and in parts of 62 immediately adjoining 53. The areas surveyed are naturally divisible into two sub-districts, which will be described in the following order:—

1ª Glencoe and Glen Nevis.
1ᵇ Island of Mull.

### 1ª *Glencoe and Glen Nevis.*

#### Highland Metamorphic Rocks.

During the last few years special attention has been given to the tectonics of the schistose area reaching from Fort William to Glen Etive, and from Glen Etive to Loch Creran by Mr. Bailey, who here furnishes an account of his interpretation of the structure of the region.

The following succession has been obtained for the schists:—

(8.) Onich Phyllites.
(7.) Appin Limestone.
(6.) Appin Quartzite (pebbly).
(5.) Ballachulish Black Slates.
(4.) Ballachulish Black Limestone, with cream coloured edge against the succeeding phyllites.
(3.) Leven Phyllites.
(2.) Glen Coe Quartzite (non-pebbly).
(1.) Moine Schists.

There are two points to notice about this succession:—

(1.) It is in most parts a natural succession, for in many places junction sections show clear evidence of passage between neighbouring members of the sequence. In this statement a doubtful exception must be admitted in regard to the relationship of the Moine Schists to the Glen Coe Quartzite. Here there is a suggestion of a passage, but this is not sufficiently definite to dispose of the suspicion that the junction of the two rocks in question may after all represent a line of disturbance.

(2.) It is, in the form given above, a descending structural succession, *i.e.*, the divisions in the upper part of the column (from 4-8), are found situated in this order in the "gape" of a major synclinal fold south of Fort William. It is considered probable, though complications introduced by fold-faulting, as explained in the sequel, prevent the attainment of certainty, that this structural succession holds throughout the whole district. On the other hand, however, there is no local evidence that it corresponds with the original stratigraphical order in which the beds were deposited.

In regard to the structure of the district, Mr. Muff, in the Summary of Progress for 1905, described a flat fold with an amplitude of at least three miles in the environs of Glen Etive. Subsequent investigation has strongly confirmed Mr. Muff's conclusion in this respect, at the same time introducing an additional feature of interest into his interpretation. To make this point clear it is necessary to consider very briefly certain local details. The rocks involved in the structure are regarded as belonging to Groups (2), (3), (4) of the table given above. The banded passage beds between the quartzite (2) and the phyllites (3) are well represented, and (4), owing to the proximity of the Cruachan granite, is in the condition of a calc-silicate hornfels. Now it seems that in the lower limb of this Glen Etive fold there exists a great hiatus where the Leven phyllites (3), perhaps a thousand feet or so in thickness, are apparently almost entirely cut out by a fold fault, so that the limestone (4) comes to rest directly upon the banded upper edge of the quartzite (2). These banded beds are numbered as Leven phyllites (3), in Fig. 1, Section I. This leads to a discrepancy between the two limbs of the recumbent fold, a discrepancy which was pointed out in Mr. Muff's original account, although it was impossible to recognise its significance until the country to the north came to be examined.

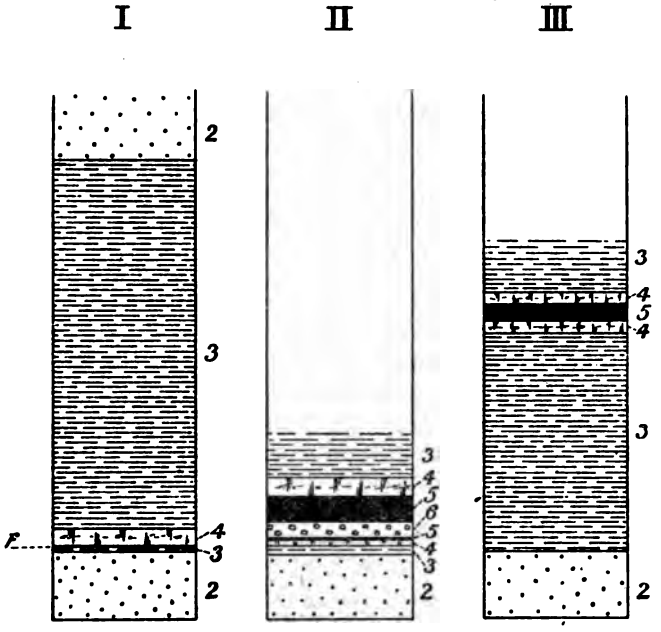


Fig. 1. Diagrammatic vertical sections showing repetition of beds in recumbent fold, as developed in Glen Etive (I), North of Loch Leven (II), near Glen Nevis (III).
F marks position of fold-fault in lower limb of fold, Glen Etive.
The numbers refer to the table given in the text.

As one proceeds in the latter direction, especially between Loch Leven and Glen Nevis, the hiatus is bridged over by the reappearance of the missing beds in their proper situation, and then the fold assumes a strictly symmetrical aspect (Fig. 1, Sec. III.).

It was in this northern district that suspicions first arose in regard to the supposed fold-fault of Glen Etive. Intermediate stages in the development of the dislocation are here suggested by the dwindling or disappearance of three recognisable rock groups (3-5) in the lower limb of the fold, while in the upper they maintain their thickness with much less important modification (Sec. II., Fig. 1).

It was very difficult, however, to find sections extensive enough and clear enough to furnish actual physical evidence in the nature of a break, in confirmation of the fold-faulting here postulated. Glen Etive, however, offers an exceptional opportunity in this respect, and a careful search was accordingly made along the junction which was now suspected to be a plane of movement. This was found upon minute investigation to be a plane of discordance. It is described by Mr. Clough as being less marked by any appearance of disruption than the well known thrusts of the North-West Highlands. It resembles rather an exaggerated plane of strain-slip foliation. It runs for the most part parallel to the bedding and foliation planes of the schists above and below, but sometimes it obviously transgresses these structures at a slight angle. Occasionally one may find small flat isoclinal folds developed in the schists above the plane which have no effect upon

those lying beneath, and *vice versâ*. At other times, however, there is evidence for the isoclinal folding of the plane itself, thus adding to the general complication.

It cannot be claimed that any appearance of excessive shearing characterises this plane, for which a throw of several miles is postulated, or distinguishes it from strain-slip planes elsewhere, which have a displacement measured in inches or yards. If the interpretation given above, of the significance of this Glen Etive plane, be correct, then it must obviously have been developed in closer connection with the folding and schist-making processes than many of the thrust planes of the North-West Highlands. The Moine Thrust, it is well known, is characterised by mylonisation leading to the destruction of the structures, schistose and otherwise, of the rocks in its immediate vicinity.

The Glen Etive fold-fault has been dwelt upon at some length as it affords the best example of a whole series of like structures of every grade of importance, for which good stratigraphical evidence has been obtained, and without which the tectonic structure of the district defies interpretation. The study of these dislocations will be continued next year.

If last year's ground work prove to be as stable as it now seems, then there will no longer be room for doubt that structurally the whole district is an assemblage of recumbent folds, broken and entire, in certain cases not less than twelve miles in amplitude; and, also, that these folds are by no means always flat, but have themselves in many cases been subsequently rucked up and bodily involved in other isoclinal folds, which, though of minor importance, are still of considerable amplitude.

### LOWER OLD RED VOLCANIC ROCKS AND ASSOCIATED INTRUSIONS.

*Glencoe.*—The mapping of the volcanic series of Lower Old Red Sandstone age in Glencoe has been practically completed by Mr. Muff. The lavas may be subdivided into lithological groups, each of which reaches a maximum of thickness in a certain area and diminishes in thickness, sometimes even vanishing altogether, when traced across the district. The positions of the various maxima are not coincident. The structure is most easily interpreted by assuming a number of centres of discharge. The fact that the members of different groups sometimes interdigitate would imply that two or more centres were in eruption contemporaneously.

*Ben Nevis.*—Some important new evidence bearing on the structure of Ben Nevis has been obtained by Mr. Muff. It shows that the structure of the mountain is comparable with that of Glencoe in several points wherein the structure of the latter is peculiar. The granite mass which forms the lower half of the hill has been proved to consist of two separate intrusions, differing in texture, and separated as to their periods of injection by a distinct interval of time. It is thus similar to the complex granite masses of Ben Cruachan in Argyllshire, and of Arran. A more detailed account is reserved until some doubtful points have been cleared up.

## 1b *Island of Mull.*

### HIGHLAND METAMORPHIC ROCKS.

*The Ross of Mull.*—The mapping of the Moine schists in this area has been continued by Mr. Bosworth, and is now almost completed. Along the coast to the west of Bunessan, between Ard an Daraich and Beinn Liathanach, a series of quartz felspar granulites is exposed similar to those mapped in the east part of the schist area in 1907 by Mr. Cunningham Craig. They may possibly be the same series repeated by a great fold, for like the eastern granulites, they pass into the pelitic series through a set of white quartzites. The western granulites only occupy a small area between the granite and the sea, and in the coast section seem to pass under the granite mass.

In the central part of the pelitic belt pale coloured calcareous bands are abundant, though rarely more than a foot in thickness. They effervesce with hydrochloric acid, most markedly in the central parts, and certainly in some cases consist mainly of calcite crystals (13,979).

There can be no doubt that these bands are essentially similar to the thin band with garnets and hornblende which Mr. Cunningham Craig described in a district a little to the south, in last year's Summary, p. 65. In the absence of zoisite and general abundance of calcite they differ from the thin siliceous bands containing garnet, hornblende, and zoisite which have been described in the Moine schists in other parts of the Highlands, but like them in all probability they represent calcareous sediments.

At the foot of Loch Assapol beds containing abundant tourmaline can be traced for a considerable distance along the strike, and in places include variable thicknesses of a rock composed essentially of tourmaline and felspar, with some quartz and biotite.

Tourmaline is also found in abundance in association with quartz and felspar in the pegmatite knots in the above district and in other localities to a less extent.*

On both sides of the tourmaline-bearing belt kyanite is present in the schist, sometimes as a very conspicuous constituent, in crystals up to three inches in length.

### PALÆOZOIC INTRUSIONS.

*Ross of Mull.*—Mr. Bosworth has obtained further evidence of the Newer Palæozoic age of the granite;† this rock being traversed on the west side of Loch na Lathaich by various dykes of mica trap and others of hornblendic lamprophyre.

The relations between the granite and the schist are of extreme complexity. Tongues of granite and isolated veins and patches are found more than half a mile away from the main mass. On

* Koch, "Notes on Mull and its Leaf-beds," *Trans. Geol. Soc. Glasgow*, vol. vii, p. 52: 1881. Heddle, "Mineralogy of Scotland," vol. 2, pl. lxxiii, fig. 1.

† 'Summary of Progress' for 1907 (*Mem. Geol. Surv.*), p. 66.

the other hand inclusions of schist, sometimes sufficiently large to be mapped, occur right in the heart of the granite area, though they are most plentiful near the margin, where excellent examples of injection breccias may be seen.

The pelitic schist near the granite, and the inclusions in the granite are often much affected. In some places new minerals are developed, and the schist is impregnated with granitic material in a most intimate manner.

The most conspicuous new minerals are sillimanite and andalusite. The latter occurs in well-fomed prisms with a pink colour, visible both in the field and in thin section. In some cases the crystals are grouped together in knots which, on weathered rock faces, form conspicuous knobs commonly an inch across and one or two inches apart. The *lit-par-lit* injection of granite material has taken place along (1) the bedding; (2) the strain-slip; and (3) the foliation.

In one notable case where the schist is bent in a sharp "V"-shaped anticline many of these granitic seams may be followed along the bedding right round the anticline; and most of them are somewhat thicker at the apex of the fold. There is also a granite core to the anticline, and taken together the facts suggest that the fold may possibly have been formed at the time of the granite intrusion. Sometimes a regular series of injections along the strain-slips of the schist connect the injections which lie along the bedding, and often from them still finer threads of granitic material have found their way along the foliation. This is seen to some extent in the instance described above.

In some areas of considerable extent the schist is so invaded by granite along the foliation that a granitoid gneiss has been formed, containing probably as much granite as schist. The inclusions in the granite are often even more completely transformed, and in places only the faintest indications of the schist remain.

In other cases the material of the schist fragments has become completely commingled with granitic matter so that no portions can be identified either as schist or granite. The product is a dark micaceous rock with a medium-grained ground mass, containing but few traces of schistosity, in which crystals of quartz and large well shaped felspars are set.

The quartz felspar granulites also seem to be much impregnated with granite. The effect most noticeable in the field is a coarser texture and the presence of large well formed felspars, but owing to the similarity in chemical and mineral composition of the two rocks, it is not easy to say whether the change is not often due simply to recrystallisation in the granulite.

### TERTIARY IGNEOUS ROCKS.

In the district of Salen Mr. Wright concentrated his attention mainly on the lavas to the south of the village and on the eastern end of the granophyre intrusion extending from Beinn Fhada across Loch Ba to the west side of Glen Forsa. The mapping as

yet has failed to disclose any points of general interest which have not been already described in Sir Archibald Geikie's account of these rocks in his "Ancient Volcanoes."*

### PLEISTOCENE AND RECENT.

*Salen.*—As pointed out in the Summary of Progress for the year 1907, p. 69, the Loch Linnhe ice-flow split on the eastern end of Mull, sending branches to north and south of the main mountain mass of the island. Mr. Wright has now ascertained that the northern branch flowed W.N.W. along the Sound of Mull as far as Salen, producing the most remarkable grooving and scoring of the rocks along its course. At Salen, however, there is a rather sudden change in the direction of the glaciation, the great mass of the ice having swept round at this point to the south-west, and passed over into Loch na Keal. The wonderful grooving and *roches moutonnées* in the pass between Salen and Loch na Keal bear witness to the power and persistence of the current which overflowed in this direction, and it is not unlikely that this outlet to the west was open for the passage of the mainland ice during the greater part of the glacial period.

At a distinctly later stage of the ice-age the local glaciers of the Mull hills evidently obtained the upper hand, and spread out over the ground where the mainland ice formerly held undisputed sway. This can be clearly proved in the case of the Glen Forsa glacier, the striae of which cross the grooves and flutings of the earlier glaciation almost at right angles. The evidence of the two ice movements is particularly well seen on the coast to the west of the mouth of the Forsa River; and since the striae of the local glacier pass up and down over trough and crest of the earlier grooving, there is no doubt as to the order of succession of the two glaciations. It is, moreover, quite clear that the ice from the mainland had vanished from this particular spot at the time when the Glen Forsa glacier attained its maximum development and spread out into the Sound of Mull. The striae of the last-named glacier maintain, right out at the shores of the Sound, the direction of the glen from which it issued, and show no signs of deflection such as would indicate the influence of another ice flow.

The deposits of the Glen Forsa glacier are distinctly morainic, and contrast strikingly with the boulder-clay of the main ice. The relation of this morainic drift to the deltaic deposits of the Forsa is clearly shown in section near Pennygown. The delta gravels here exposed, which were formed at the time of the 25-foot beach, overlie the moraine of the Glen Forsa ice. Beneath the moraine, however, are gravels indistinguishable from those above it, but it is by no means clear at what period these were formed. The only conclusion that can be safely drawn is that the morainic glaciation is earlier than the formation of some part of the delta built out at this point during the period of the 25-foot beach.

* "The Ancient Volcanoes of Great Britain," 1897, p. 395.

*Ross of Mull.*—Mr. Bosworth found the 100-foot raised beach well developed in the valley between Loch Assapol and Bunessan, and in the valley east of Cnoc an-t-Suidhe. In both cases the streams have cut through the beach into the dark boulder clay beneath, on which the beach material is seen to rest.

### ECONOMICS.

*Ross of Mull.*—Mr. Bosworth states that the Ross of Mull granite has been used for the sea-wall at Bunessan, and also in some of the buildings.

Alongside the road to the pier the quartz schists have been quarried both for the sea-wall and for road-making. In other localities raised beach gravel or decomposed portions of basaltic lavas are dug and scattered on the roads.

A scheme is now on foot for working the flaggy mica schists for roofing slabs, which it is said will have a peculiar architectural beauty. Operations have been commenced near Scoor, and it is reported that the stone is to be used to replace the black slates lately used in re-roofing Iona Cathedral. There are some indications of former working in these schists.

Along the north-east side of Loch na Lathaich and the Bunessan River, the basalt platform is overlaid by gravels of the 100-foot beach. The line of springs coming out along the junction affords to Bunessan a somewhat scanty supply of water.

## 2.—North and Central Highland District.

Comprising parts of the Counties of Caithness, Inverness, Perth, and Argyll.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M., }
Mr. E. M. Anderson, M.A., B.Sc., } Geologists.
Mr. R. G. Carruthers, }

Field Work has been carried on during the summer of 1908 on either side of the Moor of Rannoch, which includes portions of the Counties of Perth, Argyll, and Inverness, and also in Caithness.

In the Central Highland area the survey of Sheet 54, the southern portion of which was mapped many years ago, has been resumed. On the west side of the Moor of Rannoch Mr. Anderson has examined a tract of ground between Kingshouse and Loch Treig, while Mr. Hinxman has been engaged on the area lying between the head of Loch Rannoch and Glen Lyon.

In Caithness, Messrs. Crampton and Carruthers have mapped the eastern coast line from Sarclet to Latheron and completed the survey of Sheet 110.

### *Inverness, Perth, and Argyll.*

#### HIGHLAND METAMORPHIC ROCKS.

*Loch Rannoch Area.*—The area mapped by Mr. Hinxman on the south side of the head of Loch Rannoch, between Gleann Chomraidh and the Dall Burn, is mainly occupied by Moine

schists of the usual quartz-biotite-granulite type, that only vary in the amount of dark mica present in different parts of the rock.

The interest of the region centres in a belt of more diversified altered sedimentary rocks that forms the hills of Leagag and Crosscraig, on either side of the Camghouran burn. The greater part of this belt is composed of a coarse flaky muscovite-biotite-gneiss, in which muscovite is usually the predominant mineral. Some bands contain numerous small idiomorphic garnets, and the rock generally is full of knots and veins of quartz or quartzo-felspathic material. Lithologically it closely resembles the typical pelitic gneiss of the Moine Series in the Northern Highlands. On the northern side of the belt the gneiss is in contact with the siliceous Moine schists, the junction being exposed in the Camghouran burn. Within the pelitic gneiss on the south side of Leagag, is a lenticular mass of highly crystalline bluish-white limestone, associated with calc-silicate bands, while nearer the northern edge of the belt, a narrow band of silvery actinolite schist has been traced along the north face of Leagag, and appears again on the south-eastern flank of Crosscraig. This rock is described by Dr. Flett as of a rather unusual type. It consists for the most part of pale green actinolite, with a small amount of muscovite, colourless chlorite, quartz, epidote, zoisite, and sphene. There are also small patches of carbonates. It probably represents an altered impure limestone.

On the south side of the belt the pelitic rock is seen in contact with a narrow outcrop of very pure, white-weathering quartzite, containing no biotite, and resembling the quartzite of Glencoe. This band is followed on the south by Moine schists, more micaceous and flaggy on the whole than those to the north of Crosscraig.

The further extension, and relation of the rocks of this group to those in Glen Lyon, have still to be worked out. There is, however, some reason to believe that they may possibly represent the Leven phyllite, Ballachulish limestone, and Glencoe quartzite of the Loch Leven and Glencoe districts, in about the same high stage of metamorphism as is met with in the most eastern part of that region.

The belt above described is cut off on the west by a powerful fault which crosses the head of Loch Rannoch and passes in a S.S.W. direction through the valley of the Allt Sloc na Creadha into Glen Lyon, whence it has been further traced south westwards to Loch Fyne. This fault may either continue the main line of the Loch Ericht fault, or may be an important branch of that dislocation. The rocks along its course in the area surveyed are much shattered and brecciated, the zone of disturbance immediately to the south of Loch Rannoch reaching to a breadth of half a mile.

A narrow strip of undisturbed Moine schists lies between this fault zone and the eastern boundary of the Moor of Rannoch granite, which approximately follows the course of the Allt Chomraidh.

*Moor of Rannoch.*—The area of schists mapped by Mr. Anderson along the western margin of Sheet 54 between the valleys of the Black Water and the Amhainn Reidh is occupied b[illegible]

continuation of the zones traced further to the west by Mr. Wright. The following zones are represented: (1) a pelitic type which may be correlated with the Loch Leven phyllites; (2) a purely siliceous type corresponding to the Glencoe quartzite; and (3) a series of granulites of intermediate composition, but mainly quartzose, which are taken to represent the siliceous schists of the Moine Series. The rocks of the pelitic zone do not present the character of an ordinary phyllite, but are mainly in the condition of a fine-grained pelitic gneiss. This alteration is probably due to the increase in the stage of metamorphism which takes place towards the east in this district. The quartzite forms an extremely narrow band which separates the other two members of the series, but is sometimes absent. The strike of the schists is pretty uniformly to the N.N.E., while the direction of stretching dips at an angle of 15° to 40° to the S.S.W.

### IGNEOUS INTRUSIONS ASSOCIATED WITH THE METAMORPHIC ROCKS.

The area extending along the shores of the Blackwater lochs, which will be covered with water on the completion of the British Aluminium Company's reservoir, has been surveyed by Mr. Anderson. It is entirely occupied by the Moor of Rannoch granite, cut by north-east porphyrite dykes. As previously shown by Mr. Kynaston, two varieties of granite are found, a pink type with brown mica but without hornblende, and a grey type in which hornblende is also present. The former rock is not confined to the margin of the intrusion, but occurs irregularly throughout the mass, and appears to merge gradually into the more basic type without any sharp line of demarcation. The hornblendic granite contains many little basic segregations with a parallel arrangement, their longer axes pointing to the north-east, while a rude orientation of the ferromagnesian minerals in the same direction can also be detected in the granite itself in some places.

Thin, nearly horizontal sills of hornblende-vogesite, similar to those referred to by Mr. Bailey in the Summary of Progress for 1905 (p. 97), are fairly numerous in the schists to the north of the area last referred to, and are cut by the north-easterly dykes. The latter occur in great numbers over most of the ground yet surveyed. The commonest type is a red porphyrite with abundant felspar phenocrysts; but the varieties are numerous, and include some of the more basic "pock-marked" dykes of the Glencoe district, as well as an occasional quartz-porphyry.

### PLEISTOCENE AND RECENT.

*Braes of Rannoch.*—The results of Mr. Hinxman's field work show that this area lies in the path of the ice sheet which moved eastwards from the great ice reservoir of the Moor of Rannoch through the hollow of Loch Rannoch and the Tummel Valley. Striae pointing E. to E.20° N. are plentiful at all elevations, and granite boulders from the Moor of Rannoch, some of very large size, lie thickly along the shores of the Loch, cover the lower slopes, and are perched on the tops of Leagag and Crosscraig to a height of over 2,400 feet.

The phenomena of the later valley-glacier phase of the glaciation are also well displayed in the district. The throats of the glens at either end of the ridge of Crosscraig are blocked with an immense accumulation of morainic material, through which the Camghouran and Dall Burns have cut deep channels down to the underlying rock. This barrier forms a part of the high level lateral moraine laid down by the main valley glacier during a period of rest, while the lower slopes and the bottom of the valley at the head of Loch Rannoch present a series of lateral and terminal moraines that mark different stages in its retreat.

## *Caithness.*

### OLD RED SANDSTONE.

The examination of the coast-section between Sarclet and Lybster by Dr. Crampton has proved that a similar upward lithological sequence exists on either side of the Sarclet anticline, *i.e.*, from Sarclet to Wick, and from Sarclet to Lybster. A comparison of the sections has also necessitated some alteration and further division of the groups (1-3) as given in the Summary of Progress for 1906, p. 86.

The Sarclet conglomerate, the lowest group (1), forms the cliff between Sarclet Head and the Stack of Ulbster, a distance of 1¼ miles. The base of the conglomerate is not seen, and its thickness can only be estimated locally as exceeding 200 feet.

The section visible in the Mill Burn, which drains Loch Sarclet, allows an estimate of about 400 feet for the thickness of the overlying group—the Sarclet sandstone (2), which occupies the coast section from Sarclet Haven to Rieragoe in the north, but south of the Sarclet anticline is cut out of the coast section by a large fault near the Stack of Ulbster. This dislocation brings down the group of purple and green mudstones, referred to in a former report as the Iresgoe group, against the Sarclet conglomerate and sandstone.

On the south side of the Sarclet arch the mudstone group is followed in upward succession by the purple and red sandstones of the hill of Ulbster (3), which are exposed on the coast for half a mile north of Ellensgoe, where they are seen resting conformably upon the mudstones and underlying a higher conglomerate.

The upper conglomerate (4) has been traced inland from Ellensgoe for a distance of 1½ miles. It occurs in three thin bands, separated by sandstone similar to the beds below, and differs from the Sarclet conglomerate in the absence of granite fragments. This conglomerate does not reach the cliff north of Sarclet, its absence there being due to the fault at Luishal, immediately to the south of Craig Hammel.

The black slates (5) first make their appearance in the beds that overlie the upper conglomerate at Ellensgoe, and to the south of that point alternate with sandstones through an ascending sequence as far as Ceann Hilligoe. Here a N. and S. fault throws down to the west a considerable thickness of red sandstones and shales (*b*) similar to those of the Brough, two miles south of Wick.

These red beds occupy the cliff for about 300 yards, and are succeeded in upward succession by rocks similar in lithological character to those at South and North Heads, Wick, and, like them, include the lowest beds in which fossil fishes have yet been obtained in any abundance. Specimens collected by Mr. Tait have been assigned by Dr. Traquair to the genera *Thursius* and *Dipterus*.

The greater part of the ground surveyed by Mr. Carruthers lies within the extensive peat-covered areas that occupy the south-western portion of Caithness. The underlying rocks here met with represent the basal members of the Caithness Flagstone series, which, as elsewhere in the county, are found to rest on a highly irregular surface of granite and schist.

A large inlier of granite was discovered around Cyplaise Hill. The basement beds of the Old Red Sandstone, in contact with the igneous rock, are composed of granitic arkose, closely similar in appearance to the granite itself, and the line of demarcation between the two rocks is most readily detected by the truncation of the thin pegmatite veins that traverse the granite. Occasional bands of an angular granite breccia with a red mudstone matrix occur in association with the arkose.

A detailed examination was also made of the interesting coast sections between Lybster and Latheron, of which a brief note appeared in last year's Annual Summary, p. 90. An important result of this further examination has been the fixing of the position of the peculiar fish fauna of Achanarras in the sequence of rocks within the Latheron syncline. This discovery was made in a limestone band exposed on the cliff-face, a quarter of a mile east of Port-na-muic and 1½ miles east of Latheron. From this locality a large collection of fish remains has been made by Mr. Tait, and determined by Dr. Traquair as comprising, with the exception of *Cheirolepis trailli* and *Osteolepis macrolepidotus*, the whole of the fauna peculiar to Achanarras.*

Dr. Traquair's report, together with a more detailed description of this discovery and its value in elucidating the stratigraphy of the Caithness Flags, are given in the Appendix.

### CRETACEOUS.

Another interesting discovery of fossils by Mr. Tait was made in a quarry of partially disintegrated sandstone about five miles south of Spital. The fossils are considered by Drs. Kitchin and Lee to present a decidedly Neocomian facies. Whether the sandstone is *in situ*, or is a large transported mass, has yet to be determined, but in any case this is, we believe, the first recorded discovery of Neocomian fossils in the Northern Highlands.†

### PLEISTOCENE AND RECENT.

The coast line of Caithness has been examined by Dr. Crampton for evidence of the rate of marine erosion, and of the advance

* It is worthy of note that the unique ichthyolite *Palaeospondylus gunni*, hitherto found only at Achanarras, is the most abundant form in the band on the coast near Latheron as at Achanarras.

† "On the occurrence of Lower Cretaceous Fossils in Caithness." By Mr. D. Tait. Read before the Edinburgh Geol. Soc., Nov. 16, 1908.

or retreat of the sea during post-glacial times. Some of the "goes" are certainly pre-glacial in origin, and have not yet been completely cleared of the shelly boulder-clay with which they were plugged during glacial times. On the other hand, the stacks between Ceann Hilligoe and Clyth shore afford evidence of comparatively recent encroachment by the sea, being capped not only by boulder-clay but also by peat, which is rapidly undergoing removal. In other localities peat of considerable thickness is found on the very verge of the cliff where it could not possibly have been originally formed, its present position being evidently due to subsequent erosion of the cliff-face. At Nybster there is an interesting example of a rock notch and platform several feet above high water mark. Similar elevated platforms occur on other parts of the Caithness coast, and can be compared with the raised beaches found in several places along the north and east coasts at an elevation of about 5 feet above high water mark. These platforms and beaches have been examined by Messrs. Wright and Muff, who consider them to be contemporaneous with the Neolithic or so-called 25 feet raised beach of more southerly localities. The short distance of this beach above high water mark in Caithness causes difficulties in distinguishing it from storm beaches of the present day, which are locally thrown up over the 5 feet raised beach.

## 3.—Airdrie and Shotts District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A.,
Mr. H. B. Muff, B.A.,
Mr. E. B. Bailey, B.A.,
Mr. T. O. Bosworth, B.A., B.Sc., } Geologists.

### MILLSTONE GRIT.

*Fauldhouse.*—Thick fireclays were observed by Mr. Bosworth in the Millstone Grit exposed in the valley of the Breich Water between Breich Bridge and Greenburn, but their exact stratigraphical position is not yet known.

### COAL MEASURES.

*Coatbridge.*—With the help of Mr. D. Tait the strata exposed in the river Calder, near Palacecraig, were measured by Mr. Clough for about half a mile south of the outcrop of the Upper Coal. The rock exposures are interrupted by obscure gaps, but the total thickness of beds between the Upper Coal and the overlying marine band, described in last year's Summary of Progress,* appears to be about 53 fms.

The intervening strata include, near the middle, a considerable thickness of soft red and yellow sandstone, and in neighbouring sections, in close association with this sandstone, mottled

* pp. 96, 130–131.

red and purple clays are found, bearing a close lithological resemblance to other clays which occur high above the marine band.

In this Palacecraig section, for some distance above the marine band, the shales are generally grey, the sandstones either yellow or greenish yellow, and thin coals are frequent. No decided red and purple colours are noticed within a vertical distance of about 25 fms. above the marine band.

In this locality it is clear that (1) the red and mottled colours come on in certain horizons below the marine band, and that (2) these colours are not characteristic of the beds that come just above the marine band. This band is a valuable stratigraphical horizon,* but it is only in a general sense that it can be called the lower limit of the red barren measures.

For the purpose of comparison, other sections of strata about this horizon were measured in the Luggie burn—the burn south of Drumpellier House, Coatbridge—and in the river Calder near the foot of this burn. These sections are within a mile and a quarter of the site of the old Drumpark Pit, from which Mr. R. W. Skipsey procured his specimens of the Drumpark marine band. They are between two and three miles west of the Palacecraig section, and differ considerably from it. In the western or Drumpark district red and mottled colours are much more prevalent than at Palacecraig, and they extend down almost to the position of the Upper Coal. Red and mottled clays were noticed in conjunction with thin seams of cream coloured and dark grey carbonaceous limestone on the west side of the Luggie burn, at an estimated height of about 60 feet above the Upper Coal, and on the south side of the river Calder nearly half a mile S.S.W. of Old Monkland Church, at an estimated height of 250 or 260 feet above the Upper Coal. None of these seams are more than two inches thick, but they are interesting from their close resemblance to seams which occur elsewhere in stratigraphical positions far above the Drumpark marine band. The thin seams at a height of about 60 feet above the Upper Coal are associated with an ironstone containing *Carbonicola*, in too poor a state of preservation to allow of specific determination.

*Plains and Salsburgh.*—The district lying east of Airdrie, Plains and Chapelhall, which has been revised by Mr. Wright, is composed almost entirely of the lower part of the Coal Measures, the strata beneath the Virtuewell Coal being alone represented to any extent. Only at Blackrig, near Salsburgh, are there any higher metals. Here, in a very limited area of steep dips, the metals up to some distance above the Airdrie Blackband are also present. Over the greater part of the district, however, even the Virtuewell Coal is absent, and the seam of main economic importance is the

* Last summer, during a re-arrangement of the palaeontological collections, specimens were brought to notice which evidently belong to another exposure of this band not mentioned in last year's Summary. These specimens were collected by Mr. Macconochie more than 36 years ago, in a railway cutting at Parkhead, south of Motherwell, in one-inch map 23. The locality has not been revisited, but from information on the old field-maps the stratigraphical position of the band is supposed to be not far from 60 fathoms above the Ell Coal.

Lower Drumgray. The Upper Drumgray is also worked in some localities to a considerable extent. The great abundance of whin renders mining uncertain, for although it is said to enhance the value of the coal in some instances, it most certainly entirely destroys it in others.

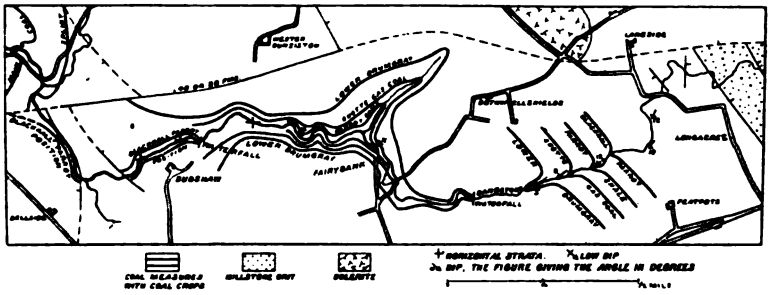


Fig. 2. Sketch Map of the Strata outcropping in the Shotts Burn above Chapelhall.

A very beautiful section of the metals between the Lower Drumgray and the Clefted Coal or Blackhall Parrot is exposed in the Shotts Burn above Chapelhall. The left bank of the stream at Bellside (Fig. 2) shows the beds in the position of the Blackhall Parrot, which do not, however, contain a coal just here, but are represented by about 23 feet of blaes with ironstone ribs and at the base a remarkable curdly ironstone. Above the blaes is a strong sandstone. The stream runs along a fault, which brings up lower metals of unknown horizon to form the opposite bank, and these lower metals form the walls of the gorge for about 150 yards round the bend towards Budshaw, where a second fault brings in the Blackhall Parrot metals once more. These now occupy the lower portions of the sides of the valley up to the Budshaw Waterfall, which is formed by the undercutting of the blaes beneath the above mentioned strong sandstone. In this section, about 12 feet above the curdly ironstone, there is a parroty shale one foot thick which probably represents the Blackhall Parrot. Passing up through the sandstone above the waterfall we reach another horizon of parrot shale, which can also be seen to die out towards the west, and, in the banks some 3½ fms. above the shale, is the Shotts Gas Coal with its roof of mussels. The latter coal is, however, not typically developed here, being only a small drossy coal of little or no value and not a gas coal. When traced west to Fairybank Bridge it improves slightly in quality before disappearing beneath the surface. The Lower Drumgray, which outcrops in the sides of the gorge some four or five fathoms above the Shotts Gas Coal, has been worked in one or two places, but is everywhere too near the surface to be of much value. Further up stream, however, it takes on more and more cover, and finally to the south of Bothwellshields ceases to show itself in the banks, passing in under a big sandstone which here crosses the stream, forming a waterfall.

Up to this point in the section the strata lie almost horizontally with, if anything, a very slight dip to the south-west, and the successive beds are only reached by the rising of the stream bed,

but at Bothwellshields the dip increases to over 10°, and, about 200 yards above the point where it disappears, the Lower Drumgray rises once more from beneath the sandstone and crops out in the banks. It is rapidly followed by the Shotts Gas Coal, the little parrot shale below it, and the Blackhall Parrot, but the sides of the valley are much obscured just at this point and little can be seen. Still lower strata with small coals occupy the stream for three or four hundred yards further east, after which a series of faults bring in the Millstone Grit.

At Bothwellshields, where the sandstone cover is thickest, the Low Drumgray has been much worked by day mines, one of which has its opening beneath the waterfall.

*Shotts.*—In the Shotts basin, part of which has been re-examined by Mr. Muff, the coals hitherto known have been those found in the lowest part of the Coal Measures as far up as the Virtuewell Coal. A small area underlain by higher beds, including a seam correlated with the Splint Coal of Wishaw, has been proved at Hartwoodhill, near Shotts. These higher beds are preserved on the downthrow side of one of the large east and west faults.

*Fauldhouse.*—Mr. Bosworth reports that the workable seams in the lower part of the Coal Measures at Fauldhouse have been almost exhausted. According to mining information, the general section should be much as follows:—

| | | |
|---|---|---|
| Shotts Furnace Coal (Ball Coal, Upper Drumgray) | 24 in. | |
| Strata | | 8 fms. |
| Shotts Low Coal | 19 in. | |
| Strata | | 4 fms. |
| Shotts Smithy Coal | 15 in. | |
| Strata, with one or two 18 in. coals about the Shotts Gas Coal position | | 25 fms. |
| Mill Coal (Crofthead 4-ft. sometimes in 2 leaves) | 36 in. | |
| Strata | | 9 fms. |
| Ball Coal (Coalinshields) | 25 in. | |
| Strata | | 4 fms |
| Main Coal (Armadale Main) | 25 in. | |
| Strata | | 12 fms. |
| Crofthead Coal (Crofthead 2-ft.) | 24 in. | |
| Strata | | 12 fms. |
| Slaty band Ironstone | 11 in. | |

### INTRUSIVE ROCKS IN THE COAL MEASURES.

Certain observations regarding the behaviour of intrusive rocks in the Coal Measures have been made by Mr. Wright in the area that he has revised. These seem to point to the conclusion that the escarpments of some of the whin outcrops, as for example near Clarkston and elsewhere in the same district, are coincident with fault lines. If this be true, as is almost certain in one or two cases at least, it might appear to be an obvious deduction that certain of the faults must be later than the intrusion of the whin floats. It is, however, by no means clear that the whins have not availed themselves of pre-existing faults as natural boundaries, or even that the faulting and intrusion may not have been to a certain extent contemporaneous. The solution of this question is obviously of both scientific and economic importance. Any case yielding evidence of the behaviour of these whin floats, especially

where they change their horizon, is therefore of distinct importance, even though it may not bear directly on the problem. Such a case was detected this autumn on the south side of the North Calder Water near Plains, where the whin, which forms the slope of the valley, rises in a series of steps or terraces from the bank of the stream. The surface of each step is distinctly chilled and vesicular, suggesting at first a series of sills one above the other with their escarpments facing the north. Several facts, however, are fatal to this view. In the first place although the Drumgray metals beneath lie almost horizontal, and the whin therefore, if a series of true sills, should have little or no dip, yet it does not reappear on the north side of the valley. Moreover, the fine grained and vesicular skin, which forms the surface of the terraces, can here and there be traced down on to their faces in such a manner as to make it pretty clear that the whin has come up from the north in a series of steps, alternately advancing along and breaking across the strata. Brownieside Burn, which is here tributary to the Calder, descends in a series of cascades over these successive steps. It is only in the lowest fall, however, that any traces of the chilled face of the terrace are preserved, and the metals against which it abutted are here entirely removed. Along the slope to the north-east, however, there are several spots at which the fine grained margin can be seen on the face of one or other of the steps, while in the stream at Loadmanford, a quarter of a mile east of Plains Station, the margin of the whin can be seen actually breaking across the strata, being chilled along a steeply inclined face in contact with the edges of the beds, and again on its horizontal surface just above. A bore at Loadmanford, the position of which is uncertain, but probably lies to the north of the stream, shows 14 fms. of whin with its surface at a depth of 22 fms. and a smaller float just above. The Virtuewell Coal appears in this bore at a depth of 8 fms., *i.e.* 14 fms. above the whin, and, a little further north where it has been mined, it is distinctly burned along the southern limit of the workings.

This evidence therefore lends support to the generally accepted view that this whin, which is one of a series forming a great ring round the districts of Slamannan and Longriggend (see p. 73), comes up from beneath these districts; and it further helps to define the manner in which transgression to higher horizons may take place.

It is moreover clear that, if the formation of vertical margins can take place, as in the present case, without the agency of faulting, it is exceedingly likely that the whin would readily avail itself of any pre-existing fault to form such a vertical margin. The coincidence of whin scarps with faults cannot therefore be regarded as conclusive evidence that the faulting is later than the intrusion of the whin.

## ECONOMICS.

Mr. Clough reports that the Haggmuir Diamond Bore, about two miles north of Coatbridge, which Messrs. Wm. Baird & Co., Ltd., started in 1907, in search of the coals in the Carboniferous

Limestone series, was completed early in the year, but unfortunately without a satisfactory result. The total depth attained was rather more than 288 fms. A thin inferior seam, taken to be the Bannockburn Main, was pierced at 221 fms., but below this no seam of value was met with, and no coal which could be confidently correlated with the Kilsyth Coking Coal. The cores below the Bannockburn Main showed very little indications of faulting, and it is to be feared, therefore, that the Kilsyth Coking Coal cannot have been originally developed in good condition in this district.

### PLEISTOCENE.

In last year's Summary of Progress, p. 98, it was mentioned that pieces of chert had been found in sand underlying boulder clay near Monkland House, Airdrie. Last spring further investigations, made by Mr. Clough and Mr. Tait, showed that pieces of chert are common in boulder clay near Coatbridge and Airdrie, and that many of these pieces have exactly the characters of the Arenig radiolarian cherts of the Southern Uplands. Subsequently it was ascertained that many years ago Mr. R. Dunlop, Shettleston, was aware of the existence of these transported cherts in the district referred to. Mr. Dunlop has not published the information he acquired about these cherts, but he corresponded about them with the late Mr. J. Bennie, of the Geological Survey, who then expressed his conviction that they were Southern Upland cherts.

## 4.—Carron and Slamannan District.

Mr. L. W. Hinxman, B.A., District Geologist.

Mr. J. S. Grant Wilson,
Mr. C. B. Crampton, M.B., C.M.,
Mr. E. M. Anderson, M.A., B.Sc.,
Mr. R. G. Carruthers,
} Geologists.

In the revision of the Carboniferous areas of Sheet 31, the south eastern shore of the Firth of Forth, including the Carronhall and Grangemouth Coalfields, was examined by Dr. Crampton, and the adjoining ground extending southwards from Polmont to the River Avon by the late Mr. Grant Wilson. Messrs. Anderson and Carruthers revised the areas of Coal Measures lying respectively to the east and south of Slamannan, and the survey of the Millstone Grit belt between Cumbernauld and Bonnybridge was completed by Mr. Hinxman.

Acknowledgment must again be made of the valuable information supplied by Mining Engineers, Colliery Proprietors, and others. Among these, thanks are specially due to the Grangemouth Coal Company, the Carron Company, and the Castlecary Fireclay Company.

### CARBONIFEROUS LIMESTONE.

*Castlecary.*—Mr. Hinxman finds that the gentle folding and east and west faulting that characterize the structure of most of

the Carboniferous area to the east of Glasgow, is well illustrated in the ground to the west and south of Castlecary. The Castlecary Limestone here forms a shallow syncline, its outcrop on the western limb of the fold being well seen in the Netherwood Quarry, and on the eastern limb in the Castlecary glen, where the limestone was formerly worked by mines from the crop.

The bottom of this glen conicides with the axis of the succeeding anticline, off which the beds dip in an easterly direction on the further side of the stream.

These folds are truncated on the south by an east and west fault with a downthrow to north of 50-60 fathoms, bringing the highest beds of the Carboniferous Limestone into contact with the Calmy Limestone and Hirst Coals. The outcrops of the latter on the west side of the syncline are seen in the wood immediately N.E. of Westerwood, and the coals and limestone appear again on the crest of the anticline on either side of the glen, as mentioned in last year's Report.

The Hirst Coals were at one time extensively worked in the basin on both sides of the fault.

### MILLSTONE GRIT.

The centre of the Castlecary basin is occupied by the lowest beds of the Millstone Grit, lying beneath a thick covering of boulder-clay. In the deepest part of the basin about 27 fathoms of strata, including the lower fireclays, are represented. The main seam of fireclay is here 25 to 30 feet above the "Cement," and 10 fathoms above the Castlecary Limestone. It has an average thickness of 9 feet.

A good section of the beds from the base of the series up to a point about 6 feet above the "Cement," is exposed on the west side of the Castlecary glen, a quarter of a mile south of the village. The dark shales that immediately overlie the Castlecary Limestone are here, and also in the Castlecary pit, only 18 inches in thickness, and are succeeded by a bed of hard white ganister which does not occur in this position in the ground further to the south. Beneath the 14in. shelly limestone which here occupies the "Cement" position, is the usual thin seam of coal. This rests in turn upon 1½ inches of loose brown sand with coaly laminae, indicating the probable "drift" origin of the coal seam.

On the further side of the anticline the strata dip steadily eastwards at low angles, and at Stein's Fireclay Works, three-quarters of a mile east of Castlecary, the base of the Millstone Grit lies 70 fms., and the Lower fireclay 60 fms., below the surface.

The Upper fireclay and ganister are worked in the Glenyards Pit, at a depth of 6 fms. The section of the seam is similar to that at the Bonnybridge workings, described in last year's Report,* but the overlying coal has thinned out to a few inches.

* 'Summary of Progress' for 1907 (*Mem. Geol. Surv.*), p. 104.

The outcrop of the coal and fireclay are seen in the Skipperton Burn, three quarters of a mile further to the west.

Upper Carboniferous plants have been obtained in this district from a horizon about 270 feet above the Castlecary Limestone. The species determined by Mr. Kidston include *Lepidodendron obovatum* Sternb., *L. aculeatum* Sternb., *Sigillaria elegans* Sternb.

### COAL MEASURES.

Owing to the sudden death of Mr. Grant Wilson at the end of the year, materials for a full report on the ground revised by him to the south of Polmont are not at present available.

The greater part of the underground information regarding the Carron and Grangemouth coalfield, which was not available for last year's Report, has now been obtained by Dr. Crampton. This area comprises part of the shallow trough of Coal Measures, five miles in width, which connects the Falkirk coalfield in the south with the Clackmannan field in the north. The surface of the ground is entirely occupied by varying thicknesses of the Carse clays, which represent the 25 feet beach deposits, or by higher stratified sands and gravels.

The greatest depth of Coal Measures is met with at Kinnaird, where nearly 100 fms. of strata were passed through before reaching the Millstone Grit. A small basin of the Virtuewell, the highest coal in the district, was formerly worked from No. 10 pit at Kinnaird.

Beneath the present course of the River Carron a deep pre-glacial channel, filled with surface deposits to a depth of 40 fms. traverses the field from west to east, and completely interrupts the continuity of all the coals whose maximum depth is less than this figure, viz., the Main, Crow, and Thin seams. The Coxrod and lower coals underlie the channel, across the floor of which they crop on either side of the coal basin.

Information recently obtained from bores put down on either side of the basin at Carmuirs and Lauriston shows that the Coal Measures are continuous beneath the alluvial deposits between Falkirk and Carron, and are not separated by Millstone Grit as represented on the existing map.

In the Grangemouth area an east and west dolerite dyke has been met with in all the coal workings, and the Main Coal is also burnt in the Carronhall field along the same line further to the west. It is thus probable that this dyke is a continuation of the east and west dyke in the Limestone Coal workings of the Herbertshire Colliery near Denny. The field is also traversed by several powerful east and west faults, the chief of which, with a downthrow of 20 fms. to the south, limits the present workings to the north. The lower coals have been lately proved by diamond bores over a wide area to the north of this fault between the Carron and Grangemouth and Airth coalfields, but are not considered of good quality. The following list gives the coal seams met with in this field with their local names:—

| | Fms. | Ft. | In. | Ft. | In. |
|---|---|---|---|---|---|
| Virtuewell (formerly worked at Kinnaird)... | ... | 2 | 9 | | |
| Strata ... ... ... ... ... ... | 12 | | | | |
| Musselband and thin Ironstone ... ... | | | | | |

| | Fms. | Ft. | In. | Ft. | In. |
|---|---|---|---|---|---|
| Strata ... ... ... ... ... ... | 10 | | | | |
| Carron Two-foot or Thin Coal ... ... | ... | 2 | 0 to 2 | 6 | |
| Strata ... ... ... ... ... ... | 6 | | | | |
| Crow Coal or Craw Coal, in two parts ... | ... | 2 | 6 | | |
| Strata ... ... ... ... ... ... | 8 | | | | |
| Main Coal or Splint ... ... ... ... | ... | 2 | 6 to 3 | 6 | |
| Strata ... ... ... ... ... ... | 6 | | | | |
| Mid Splint or Little Splint ... ... ... | ... | 1 | 2 | | |
| Strata ... ... ... ... ... ... | 5 | | | | |
| Coxrod Coal ... ... ... ... ... | ... | 2 | 0 to 2 | 6 | |
| Strata ... ... ... ... ... ... | 2 | | | | |
| Lower Coxrod Coal ... ... ... ... | ... | 1 | 6 to 3 | 0 | |
| Strata ... ... ... ... ... ... | 11 | | | | |
| Auchingane or Mill Coal ... ... ... | ... | 1 | 6 | | |
| Strata ... ... ... ... ... ... | 16 | | | | |
| Brighton Main or Ball Coal ... ... ... | ... | 1 | 2 | | |
| Strata ... ... ... ... ... ... | 7 | | | | |
| Glenfuir or Gutterhole Coal... ... ... | ... | 1 | 9 | | |
| Strata ... ... ... ... ... ... | 5 | | | | |
| Coalinburn Coal ... ... ... ... | ... | 1 | 0 | | |
| Strata ... ... ... ... ... ... | 7 | | | | |
| Slatyband Ironstone (locally) ... ... | ... | 2 | 0 | | |

*Greengairs and Longriggend.*—The revision of the area around Greengairs and Longriggend has been completed by Mr. Carruthers. Much new information concerning the coal outcrops and faulting of the field has been collected, but points of general interest are few. Some interesting evidence has, however, been obtained regarding the formation of the well known steam coals and anthracites of the Greengairs-Longriggend field. This has always been supposed to be due to the presence of an underlying sill of igneous rock (or " whin float "), probably a prolongation of that cropping out to the south round Caldercruix. Definite evidence of the presence of this "whin," however, seems never to have been found in the working of the coals, nor does the sill appear at the surface anywhere in the district.

A small series of analyses of coal from the anthracite region has been compared with some from the same seams elsewhere, where they assume a more normal character.* Two points were considered, namely (1) the " fuel ratio "—*i.e.*, the ratio between the percentages of fixed carbon and of volatile combustible matter in the coal proper—and (2) the percentage of ash in the coal.

Taking the seams in descending order, we have the following tabular statement:—

LADY GRANGE COAL.

| | Gartness. | Arden No. 2 Pit. |
|---|---|---|
| Fuel ratio ... ... | 7·0 | 2·0 |
| Ash percentage ... | 4·0 | 8·8 |

UPPER DRUMGRAY COAL.

| | West Longrigg. | Greyrigg. | Arden No. 10 Pit. | Kippsbyre. |
|---|---|---|---|---|
| Fuel ratio ... | 3·42 | 4·2 | 2·3 | 1·3 |
| Ash percentage.. | 4·00 | 4·0 | 7·5 | 5·3 |

* For these analyses we are indebted to Mr. Duncan of the Arden Coal Co., and to Mr. C. T. Clough. Some have also been taken from the Colliery Guardian's " Analyses of British Coals and Coke."

LOWER DRUMGRAY COAL.

| | Longrigg. | Darngavil. | Arden No. 10 Pit. | Rosehall. |
|---|---|---|---|---|
| Fuel ratio ... | 13·7 | 12·0 | 4·0 | 1·5 |
| Ash percentage.. | 2·04 | 2·25 | 2·35 | 2·5 |

(In this case it will be seen that the ash percentage remains practically unchanged.)

Conclusions based on these results can only be tentative, since the number of analyses is far too small and the localities are often far apart. Nevertheless it may be said that a rise of the fuel ratio (*i.e.*, as the coal loses volatile matter) is accompanied by a decrease in the ash percentage. The figures lend no support to the theory that the anthracitization of the coals is caused by the baking effect of some underlying sill of igneous rock, since if this were so the ash percentage should rise with the fuel ratio. Neither can it be said that the anthracitization was caused by some overlying igneous rock, now removed by denudation, for it is a general rule in the district that the lower the seam the more anthracitic it becomes. A further point against any alteration by an igneous sill is supplied by the fact that at Darngavil, where first-class steam coals and also a certain amount of anthracite are developed, deep bores, passing far below the seams worked, have failed to reveal any trace of igneous rock.

Taking all the facts together, it must be said that the balance of the evidence points rather to the anthracitization of the coals being analogous to that in South Wales,* *i.e.*, it arises from an original difference in composition rather than any baking effect of a subsequent igneous intrusion.

Additional information, obtained during the past year, has enabled several corrections and additions to be made to the general section of the coal of the Greengairs district given in last year's Summary, p. 106. The revised section of the Lower Coals is given below.

GENERAL SECTION OF THE LOWER COALS IN THE GREENGAIRS DISTRICT.

| | Fms. |
|---|---|
| *Upper Drumgray Coal*— | |
| Sandstone strata with two thin coals (Mid Drumgray) ... ... | 13 |
| *Lower Drumgray or Coxrod Coal*, 9 to 14 inches— | |
| Sandstone strata ... ... ... ... ... ... ... | 3 to 4 |
| *Coal* 6 to 18 inches. (Outcrops on roadside at the west end of Blacktongue Plantation)— | |
| Sandstone strata ... ... ... ... ... ... ... | 2 to 3 |
| Blaes and I.S. occasionally with 'mussels' ... ... ... | 1 |
| *Coal* 9 to 19 inches. (Outcrops on east bank of stream between Loanhead and Shiels)— | |
| Sandstone strata ... ... ... ... ... ... ... | 2½ to 6 |
| *Coal* (often with a thin rib of parrot coal) 11 to 26 inches. ('Smithy' coal worked at West Glentore Colliery)— | |
| Strata ... ... ... ... ... ... ... ... ... | 4 to 5 |
| *Coal* 16 to 27 inches, often with a thin slate parting. (Best developed round Auldshields, where there is a thin black-band rib in bottom of coal— | |
| Sandstone strata ... ... ... ... ... ... ... | 6 to 10 |

* "The Coals of South Wales," p. 63, &c. (*Mem. Geol. Surv.*), 1908.

| | Fms. |
|---|---|
| *Mussel-band Ironstone* in beds. (Outcrops above the stream at Auldshields, where it is an impure black-band, with a little coal. There is a thick fireclay below)— | |
| Sandstone strata ... ... ... ... ... ... ... | 3 |
| Strata with several thin *Coals* and *Ironstones*. (Contains a thin black-band rib at Auldshields) ... ... ... ... ... | 3 to 6 |
| Sandstone ... ... ... ... ... ... ... ... | 4 to 7 |
| Auldshields *Slaty-band Ironstone* position. (Outcrops along the stream above and below Auldshields Bridge. There is a thick fireclay below this seam.) | |

### DOLERITE SILLS.

Mr. Anderson reports on the relations of the dolerite sill of Avonbridge, which underlies a part, at least, of the Slamannan coalfield, to the lower seams of the Coal Measures. At Binniehill its upper surface cannot be less than 60 fms. below the Coxrod Coal, or 15 fms. below the approximate horizon of the Slaty-band Ironstone. A mile further to the east, however, the Coxrod Coal is badly burnt by the igneous rock. The condition of certain thin seams seen in the Drumtassie burn near Burnhead also shows that the sill cannot be far beneath, and it comes to the surface a little further to the east, apparently along a line of fault. From surface evidence the sill must be at least 100 feet in thickness. Near Canty, four miles S.E. of Binniehill, the Main Coal of the Armadale section has been mined for some distance beneath the dolerite, and is but little affected. The Mill Coal, in parts at least of the Armadale coalfield, is separated by a considerable thickness of sedimentary strata from the lower margin of the sill.

The Mill Coal lies 25 fathoms above the Slaty band Ironstone, showing to what a considerable extent the intrusion has changed its level in passing eastwards from Slamannan to Armadale.

### ECONOMICS.

*Coal.*—The coals at present raised in the Grangemouth field are the Thin Coal, Craw Coal, and Upper and Lower Coxrod Coals. The Main and Auchingane coals have also been wrought to some small extent.

At Carronhall the seams now being worked are the Crow, the Main, and the Upper and Lower Coxrods.

*Oil Shale.* A sample from an oil shale 4 feet 6 inches thick, lying a short distance above the Auchingane Coal at the Manuelrigg Collieries, has been analysed for Mr. Wilson by Mr. D. R. Stewart, Chemist to the Broxburn Oil Company, with the following result:—

Crude Oil—16·0 gallons per ton.
Sp. gravity, ·924.
Setting point, 89° F.
Sulphate of ammonia, 9·4 lbs. per ton.

Another sample from the Polmont Burn at Brightons, presumably on the same horizon, gives:—

Crude Oil—19·2 gallons per ton.
Sp. gravity, ·922.
Setting point 87° F.
Sulphate of ammonia, 9·8 lbs. per ton.

The amount of sulphate of ammonia obtained in these laboratory analyses is only half that got when a large quantity of shale is dealt with.

*Fireclay.*—The Lower Fireclay at Castlecary, which lies 10 fms. above the Castlecary Limestone, and on the same general geological horizon as the fireclay wrought at Glencryan, Gain and Glenboig, is raised by the Castlecary Fireclay Company for the manufacture of bricks, blocks and other fireclay goods. A silica brick is also made from the ganister above the limestone with a certain admixture of fireclay, and used for steel furnace linings.

Similar products are manufactured by Messrs. Graham at the Glenyards Pit from the fireclay and ganister of the Upper Fireclay seam.

A fireclay immediately overlying the Lower Coxrod coal is raised at Grangemouth for the manufacture of ordinary fire bricks. The same clay is also used at Carron for brick-making, but is not put on the market.

*Limestone.*—The Castlecary Limestone is raised and burnt at the Castlecary Fireclay Company's works for building and agricultural purposes. The top portion of the seam, which is here five feet in thickness, is also used as a flux in blast furnaces.

An analysis of this limestone made by Mr. R. R. Tatlock, City Analyst, Glasgow, shows it to be of good quality, containing nearly 90 per cent. of calcium carbonate, with small quantities of silica, alumina, iron and magnesia.

*Building Stone.*—A sandstone in the lower part of the Coal Measures, immediately beneath the Auchingane Coal, is largely quarried at Polmont. The total thickness of the sandstone is 39 feet, of which 25 feet are exposed in the present working face of the quarry. The upper 4½ feet is a white flaggy rock, quarried for flagstones, the remainder a somewhat banded and more or less false-bedded freestone. Except for its streaky character, it affords a first-class building stone. The rock is machine dressed at the quarry into sills, lintels, jambs, &c., and finds a ready market locally and in Edinburgh.

*Setts and Road Metal.*—A number of sett quarries have been wrought from time to time in the sill of dolerite to the south of Avonbridge. The rock varies from fine-grained to very coarse in texture, and in much of it the joints are sufficiently far apart to furnish not only setts, but kerbs and other large pieces. A certain amount of road-metal was also got from these quarries. The coarser material was used for machine breaking, while the hand breakers preferred the "cleaner" and finer-grained variety.

*Peat.*—A large number of bores have lately been put down on the lands of the Palacerigg Labour Colony for the purpose of proving the depth and nature of the peat in the extensive mosses around Fannyside Loch.

The result of the bores in the Burntrigg Moss on the north-west side of the loch gives an average depth of 6·4 feet for the brown peat, with a maximum depth of 9 feet; and for the underlying black peat—average 7·4 feet, maximum 12 feet. In the

Blackmyreknoll Moss, south of the loch, the depths are—Brown peat, average 10·8 feet, maximum 20 feet; Black peat, average 5 feet, maximum 6·5 feet. The brown peat, which everywhere forms the upper portion of the moss, is a loose fibrous peat of good quality, and would probably repay exploitation for moss litter and packing material.

## II.—PALÆONTOLOGICAL WORK.

Palæontological work in Scotland was carried on under the general supervision of Dr. Kitchin, by Dr. Lee with the assistance of Messrs. Macconochie, Tait, and McVey.

During the year an important collection of Old Red Sandstone fishes was made by Mr. Tait in Caithness; the results of the study of these fishes by Dr. Traquair will be found on pp. 92, 93 of the Appendix. At the same period Mr. Tait made an interesting discovery of Mesozoic fossils in the Leovad Sand Pit, eight miles a little W. of N. of Latheron, and half a mile south of Tacher, seven miles S.S.W. of Loch Watten, Caithness. At this locality curious concretions locally known as "Egg-stones" have been found, and described by Mr. Tait in the Transactions of the Geological Society of Edinburgh, March, 1907. In a second paper read in November, 1908, Mr. Tait gives an account of the mode of occurrence of the fossils recently obtained. These include Lamellibranchs, Gasteropods, and Cephalopods, only a few being specifically determinable on account of the coarse nature of the matrix. The better preserved specimens were submitted to Dr. F. L. Kitchin, who determined them as follows:—

Pecten (Syncyclonema) orbicularis *J. Sow.*
Pteria (Oxytoma) sp.
Desmoceras?
Craspedites sp. (probably sp. nov.)
Hamites sp.
Crioceras sp. (1) (fragment illustrating a simply costate stage).
Crioceras sp. (2) (fragment illustrating a spinous stage).

Dr. Kitchin remarks that the fossils are of Cretaceous age and that the assemblage, taken as a whole, points to a Lower Cretaceous rather than an Upper Cretaceous horizon. He also thinks it probable that they are either Valanginian or Hauterivian, that is, from a lower horizon than those from Moreseat, which were believed by Mr. Jukes-Browne to be of Aptian age.

The relations of the sediments, that have yielded these fossils, to the underlying Old Red Sandstone have not been definitely ascertained, but the discovery is of great interest, as it marks the most northerly limit of Neocomian strata at present known in the British Isles.

Valuable additions have been made to our knowledge of the extension of the Middle Coal Measures of Scotland in the southern part of the country. From the cores of a bore put down near Kirkconnel in Dumfriess-shire, Mr. Macconochie obtained a suite of plants which were submitted to Dr. R. Kidston, who kindly supplied the following statement on the results of his examination of the plants. It is of great importance as it shows the probable position of the boundary line between the Lower and the Middle Coal Measures in that area.

"*Note on a small collection of fossil plants from No. 2 Diamond Bore, Kirkconnel, Dumfries. By Dr. R. Kidston, F.R.S.*

The collection made at No. 2 Diamond Bore, Kirkconnel, contains the following species:—

Sphenopteris tenuissima *Presl*
*Hor.* 15 fms. below Marine Band (=44 fms. from surface).
Mariopteris sp.
*Hor.* 19 fms. above Marine Band (=10 fms. from surface).
Neuropteris tenuifolia *Schloth.* sp.
*Hor.* 15 fms. below Marine Band.
Calamites undulatus *Sternb.*
*Hor.* 6 fms. above Marine Band.
Calamocladus charaeformis *Sternb.* sp.
*Hor.* 16 fms. below Marine Band.
Sphenophyllum cuneifolium *Sternb.* sp.
*Hors.* 15 fms. below Marine Band.
16 fms. below Marine Band.
Lepidodendron rimosum *Sternb.*
*Hor.* 19 fms. above Marine Band.

Taking the Marine Band as a dividing line the fossil plants collected above it are:—

Mariopteris sp.
Calamites undulatus *Sternb.*
Lepidodendron rimosum *Sternb.*

and those from below it are:—

Sphenopteris tenuissima *Presl*
Neuropteris tenuifolia *Schloth.* sp.
Calamocladus charaeformis *Sternb.* sp.
Sphenophyllum cuneifolium *Sternb.* sp.

Of the two species specifically determined from above the Marine Band, both occur in the Westphalian and Lanarkian Series, and of the four species collected from below it, *Calamocladus charæformis* and *Sphenophyllum cuneifolium* are also common to both the Westphalian and Lanarkian Series, but *Neuropteris tenuifolia* is one of the most characteristic species of the Westphalian Series, and I have hitherto never met with it out of that series in Britain. *Sphenopteris tenuissima* is a very rare species, but it also appears to be restricted to the Westphalian Series, where it occurs in the Yorkshire Coalfield.

Although the number of species collected from the bore is small, they are all Westphalian plants, and as two of them are only known from that horizon, the rocks from which these at least were derived—the beds below the "Marine Band"—must I think be regarded as of Westphalian Age (Middle Coal Measures)."

The cores from a number of deep bores have been examined by the Palæontological Staff, and, thanks to the liberality of the owners, important horizons could be traced in areas where they had not previously been discovered. The characteristic alum-shale containing *Edmondia punctatella* (Jones) and, so far as known, always occurring immediately below the Calmy Limestone, has been found in this position by Mr. Tait in the cores of two bores, the one at Rashiehill near Slamannan, Stirlingshire, the other at Haggmuir near Coatbridge. From the cores of a

bore near Plean, Stirlingshire, Mr. Tait obtained at an horizon near the base of the Millstone Grit, many specimens of Lamellibranchs which Dr. Wheelton Hind has identified as belonging to the fauna of American facies mentioned in the Summary of Progress for 1905, and described at length in the Transactions of the Royal Society of Edinburgh for September, 1908.* It is interesting to note the occurrence in these beds of *Edmondia nebrascensis* (Geinitz), a species first described from the Upper Carboniferous rocks of Nebraska, and found also in the Upper Carboniferous rocks of Russia.

Mr. Tait also found the *Edmondia punctatella* bed in a railway cutting near Hogganfield Loch, N.E. of Glasgow, and in the bank of a stream near Milton of Campsie.

The revision of fossil lists for Memoirs to be shortly issued has brought out a few points of interest regarding the Bryozoan fauna of Scotland. A preliminary examination of the members of the sub-order *Trepostomata* Ulrich has shown that the genus *Stenopora* Lonsdale is abundantly represented in the Carboniferous Limestone Series of Central Scotland by Ure's "*Millepore*," redescribed by the late John Young as *Tabulipora urei*. In the upper portion of the Calciferous Sandstone Series of Southern Scotland, the genus is represented by a much larger form, agreeing with *Stenopora howsei* (Nicholson). To what extent these two forms may claim to be distinct from the "*Chætetes tumidus*" of authors, cannot be settled without a close examination of Phillips' type specimen of "*Calamopora tumida*." The Carboniferous Limestone Series of Central Scotland contains a representative of the genus *Batostomella* Ulrich, agreeing with *Batostomella miliaria* (Nicholson) [*Monticulipora tumida* var. *miliaria* Auct.]. Mr. A. Macconochie obtained long ago from a bed in the upper portions of the Calciferous Sandstone Series of Arbigland, Kirkcudbrightshire, a few specimens of a form which appears to be an undescribed species referable to the genus *Anisotrypa* Ulrich.

With more abundant materials for comparison and a fuller knowledge of the conditions under which these organisms lived, it is not impossible that they may prove useful in zonal work, and as they are specially well adapted to microscopical investigation, minute changes in structure due to evolution, could be detected, if present.

Large suites of specimens illustrating the newly issued Memoirs by Dr. B. N. Peach on "The Higher Crustacea of the Carboniferous Rocks of Scotland," by Dr. Wheelton Hind on "The Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland," and by Miss G. L. Elles, D.Sc., and Mrs. Shakespear, D.Sc., on the British Graptolites, were placed among the exhibited specimens in the Survey Gallery of the Royal Scottish Museum, and this work has been carried out by Mr. A. Macconochie.

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* "On the Lamellibranch and Gasteropod fauna found in the Millstone Grit of Scotland." By Dr. Wheelton Hind, *Trans. Roy. Soc. Edin.*, vol. xlvi., pt. ii., p. 331.

The Geological Survey specimens which have been figured or described during the year are as follows:—

## In the Memoirs of the Geological Survey of Great Britain.

*Monograph on the Higher Crustacea of the Carboniferous Rocks of Scotland.*

### By Dr. B. N. Peach, F.R.S.

Tealliocaris loudonensis *sp. nov.*, pl. i., figs. 1–7, p 9.
„ woodwardi (*R. Etheridge, jun.*), pl. ii., figs. 1–6, p. 18.
„ etheridgei (*Peach*), pl. iii., figs. 1, 2, p. 22.
„ „ *var.* lata *Peach*, pl. iii., figs. 3, 4, p. 23.
„ robusta *sp. nov.*, pl. iii., figs. 5–8, p. 24.
„ „ *var. nov.*, pl. iii., figs. 9–12, p. 25.
„ tarrasiana *sp. nov.*, pl. iii., figs. 13–16, p. 26.
„ formosa (*Peach*), pl. iii., figs. 17, 18, p. 27.
Pseudo-Galathea macconochiei (*R. Etheridge, junr.*), pl. iii., figs. 19–22, p. 28.
Anthrapalaemon russellianus (*Salter*), pl. iv., figs. 1–5, p. 30.
„ „ *var.* spinulosus *var. nov.*, pl. iv., fig. 7, p. 36.
Perimecturus parki (*Peach*), pl. v., figs. 1–5, p. 40.
„ „ *var.* duplicicarinatus *var. nov.*, pl. v., fig. 6, p. 41.
„ stocki *sp. nov.*, pl. vi., fig. 1, p. 42.
„ elegans *sp. nov.*, pl. vi., figs. 2–6, p. 44.
„ communis *sp. nov.*, pl. vii., figs. 1–5, p. 47.
„ ensifer *sp. nov.*, pl. vii, figs. 8–14, p. 49.
Palaeocaris scotica *Peach*, pl. viii., figs. 1–5, p. 54.
„ landsboroughi *sp. nov.*, pl. viii., figs. 8–10, p. 55.
Palaemysis dunlopi *sp. nov.*, pl. viii., figs. 12–14, p. 57.
„ couttsi *sp. nov.*, pl. viii., figs. 16–19, p. 59.
„ tenuis *sp. nov.*, pl. viii., figs. 20–24, p. 60.
„ *sp. ind.*, pl. viii., fig. 25, p. 60.
Anthracophausia dunsiana *sp. nov.*, pl. ix., figs. 1–10, p. 61.
„ „ *var.* obesa *var. nov.*, pl. ix., figs. 11–15, p. 66.
„ traquairi (*Peach*), pl. x., figs. 1–5, p. 67.
Crangopsis socialis *Salter*, pl. x., figs. 7–11, p. 69.
„ eskdalensis (*Peach*), pl. xi., figs. 1–7, p. 80.
„ elegans (*Peach*), pl. xi., figs. 9, 10, p. 81.
„ magna *sp. nov.*, pl. xi., fig. 15, p. 75.
„ couttsi *sp. nov.*, pl. xii., figs. 1–7, p. 76.

## In the Transactions of the Royal Society of Edinburgh, Vol. XLVI., Part II. (No. 15), 1908.

*On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland.*

### By Dr. Wheelton Hind, B.S., F.R.C.S., F.G.S.

Palaeolima retifera (*Shumard*), pl. i., fig. 1, p. 337.
Aviculopecten regularis *sp. nov.*, pl. i., figs. 2, 3, p. 341.
„ neglectus (*Geinitz*), pl. i., figs. 4–6, p. 341.
„ obliquus *sp. nov.*, pl. i., fig. 8, p. 340.
Limatulina alternata (*M'Coy*), pl. i., figs. 9, 10, p. 338.
Aviculopecten whitei *Meek*, pl. i., figs. 11–13, p. 338.
Posidoniella laevis (*Brown*), pl. i., fig. 15, p. 342.
Myalina verneuili (*M'Coy*), pl. i., fig. 16, p. 342.
Nuculana laevistriata (*Meek and Worthen*), pl. i., fig. 17, p. 343.
Nucula gibbosa *Flem.*, pl. i., figs. 18, 19, p. 343.
Modiola subelliptica *Meek*, pl. i., fig. 20, p. 343.
Grammatodon tenuistriata (*Meek and Worthen*), pl. i., fig. 21, p. 344.
Protoschizodus curtus (*Meek and Worthen*), pl. i., figs. 22, 23, p. 345.

Schizodus wheeleri (*Swallow*), pl. i., figs. 25–28, p. 345.
? Anthracomya truncata *sp. nov.*, pl. i., figs. 29–30, p. 346.
Edmondia excentrica *sp. nov.*, pl. ii., figs. 31, 32, p. 347.
„ sulcata (*Phill.*), pl. ii., fig, 33, p. 348.
„ nebrascensis (*Geinitz*), pl. ii., fig. 34, p. 358.
„ lyelli *Hind*, pl. ii., fig. 35, p. 348.
Sanguinolites occidentalis (*Meek and Hayden*), pl. ii., figs. 36–38, p. 348.
? Allorisma reflexa *Meek*, pl. ii., fig. 39, p. 349.
Tellinomorpha hindi *Bolton*, pl. ii., figs. 40–42, p. 349.
Solenomorpha cylindrica *sp. nov.*, pl. ii., figs. 43, 44, p. 350.
Solenomya brevis *sp. nov.*, pl. ii., figs. 45–47, p. 351.
Prothyris elegans *Meek*, pl. ii., figs. 48–50, p. 353.
Loxonema nanum *de Kon.*, pl. ii., fig. 51, p. 353.
Naticopsis brevispira (*de Ryckholt*), pl. ii., figs. 52–53, p. 354.
Entalis meekianum (*Geinitz*), pl. ii., fig. 54, p. 355.
Ptychomphalus marcouianus (*Geinitz*), pl. ii., fig. 55, p. 354.
Bellerophon marcouianus *Geinitz*, pl. ii., fig. 56, p. 356.
Euphemus orbignyi (*Portlock*), pl. ii., figs. 57, 58, p. 355.
Macrocheilina sp., pl. ii., fig. 59, p. 354.
Solenomya cylindrica *sp. nov.*, pl. ii., figs. 60, 61, p. 351.

## In the Palæontographical Society's Volume for the Year 1908.

### *A Monograph of British Graptolites.*

By Miss G. L. Elles, Sc.D., and Mrs. Shakespear, D.Sc.

Petalograptus palmeus (*Barrande*), pl. xxxii., fig. 1*d*, p. 274.
„ „ *var.* ovato-elongatus (*Kurck*), pl. xxxii., figs. 4*c*, 4*d*, p. 277.
„ altissimus *sp. nov.*, pl. xxxii., fig. 7*a*, p. 281.
Cephalograptus cometa (*Geinitz*), pl. xxxii., fig. 10*c*, p. 285.
Glossograptus hincksi, *var.* fimbriatus (*Hopkinson*), pl. xxxiii., figs. 3*b*, 3*c*, 3*d*, p. 312.
„ armatus *Nicholson*, pl. xxxiii., figs. 5*c*, 5*d*, 5*e*, p. 312.
Hallograptus mucronatus, *var.* bimucronatus (*Nicholson*), pl. xxxiii. figs. 8*a*, 8*b*, 8*e*, p. 323.
„ „ *var.* nobilis *var. nov.* pl. xxxiii., figs. 9*a*, 9*b*, 9*c*, 9*d*, p. 324.
Thysanograptus harknessi (*Nicholson*), pl. xxxiv., figs. 1*b*, 1*c*, 1*d*, p. 325.
„ „ *var.* costatus (*Lapworth*), pl. xxxiv., fig. 2*a*, p. 327.
Nymphograptus velatus *gen.* and *sp. nov.*, pl. xxxiv., figs. 4*a*, 4*b*, p. 329.
Retiograptus geinitzianus *Hall*, pl. xxxiv., fig. 7*a*, p. 316.
Gladiograptus geinitzianus (*Barrande*), pl. xxxiv., figs. 8*a*, 8*c*, p. 336.
„ „ *var.* angustidens *var. nov.*, pl. xxxiv., p. fig. 9*a*, p. 338.
Plegmatograptus nebula *sp. nov.*, pl. xxxiv., figs. 14*a*–14*d*, p. 340.
Dimorphograptus confertus (*Nicholson*), pl. xxxv., fig. 3*c*, p. 349.
„ *cf.* longissimus (*Kurck*), pl. xxxv., fig. 8*c*, p. 354.

## III.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

### A. ENGLAND AND WALES.

### I.—MAPS.

#### (*a*) *Four Miles to One-inch.*

New Series. Solid Edition.

Sheet 8 (Flamborough Head and Grimsby), price 2s.
Sheet 14 (Aberystwyth, Carmarthen, Hereford, &c.), price 2s. 6d.
Sheet 18 (Bristol, Cardiff, Crewkerne, Swansea), price 2s. 6d.
Sheet 19 (Bath, Guildford, Abingdon, Southampton), price 2s. 6d.
Sheet 22 (Plymouth, Exeter, Lyme Regis, &c.), price 2s. 6d.

#### (*b*) *One-inch Maps (New Series).*

(Colour-printed, price 1s. 6d. each.)

Sheet 125, Derby (Drift).
Sheet 126, Nottingham and Newark (Drift).
Sheet 295, Taunton and Bridgwater (Drift).
Sheet of the Oxford District (Drift).
A colour-printed drift-edition of Sheet 54 (Scarborough) has been issued in place of the old hand-coloured edition.

#### (*c*) *Six-inch Maps of Mining Districts.*

The undermentioned six-inch maps have been published with geological information (uncoloured, price 1s. 6d. each): coloured copies can also be obtained at an additional charge for colouring:

Brecknockshire —46 S.W., 47 N.W., N.E, 51 N.W.
Carmarthenshire.—54 S.W., S.E, 55 N.E., S.W., 57 N.W., N.E, S.E., 58 N.W., N.E., S.E., 59 N.W., S.W.
Cornwall.—63 N.W., N.E, S.W., S.E., 67 S.W., 69 N.W., N.E., S.W., S.E., 73 N.W., 75 N.W., N.E.
Glamorganshire.—6 S.E., 7 S.E., 12 N.E., S.W., S.E., 13 N.W., S.W., 14 N.E., S.E., 19 N.W., N.E., S.W., S.E., 20 N.W., S.W., 22 N.E., S.E., 23 N.W., N.E., S.W., S.E., 28 N.W., N.E., S.W., S.E., 29 N.W., S.W., S.E., 36 N.W., N.E., S.W., S.E., 37 N.W., N.E., S.W., 42 N.W.
Monmouthshire.—11 S.W., S.E., 17 N.E., S.E., 18 N.W., S.W., S.E., 22 N.E., S.E., 23 N.W., N.E., S.W., 27 N.E., 28 N.W., S.W.

#### (*d*) *Six-inch Reference Maps.*

Seventy-seven MS. coloured copies of six-inch sheets have been made from the field-copies, and deposited in the Office for Public Reference. They are as follows:—

Buckinghamshire.—37 S.W., S.E.
Cumberland.—32 N.W., N.E., S.W., S.E.
Derbyshire.—39 N.E., 40 N.W., S.W., 45 N.W., S.W., 50 N.W.
Durham.—39 N.W., N.E., S.W., S.E.

Flintshire.—1 N.E., S.W., 2 S.E., 4 N.W., S.E., 5 S.W., 9 N.W., S.W., S.E., (part), 12 S.E., 17 N.E., S.E.
Leicestershire.—7 N.W., N.E., S.W., S.E.
Northumberland.—31 N.W., N.E., S.W., S.E., 32 N.W., N.E., S.W., S.E., 37 N.W., N.E., S.W., S.E., 38 N.W., N.E., S.W., S.E., 39 N.W., N.E., S.W., S.E.
Nottinghamshire.—19 N.W., S.W., 23 N.W., N.E., S.W., S.E., 24 N.W., S.W., 27 N.E., 28 N.W., N.E., S.W., S.E., 29 N.W., N.E., S.W., S.E., 30 N.W., N.E., S.W., S.E., 31 N.W., S.W.
Oxfordshire.—41 S.E.
Yorkshire.—173.

## II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1907, pp. 175. Price 1*s.*

The Coals of South Wales, with special reference to the origin and distribution of Anthracite, by Aubrey Strahan, M.A., Sc.D., F.R.S., F.G.S., and W. Pollard, M.A., D.Sc., F.G.S., assisted by E. G. Radley, pp. 97. Price 1*s.* 6*d.*

The Geology of the Country North and East of Harrogate by C. Fox-Strangways, F.G.S. Second edition. (Explanation of Sheet 62, 93 N.W. Old series.) pp. 100. Price 2*s.* 6*d.*

The Geology of the Southern part of the Derbyshire and Nottinghamshire Coalfield, by W. Gibson, D.Sc., F.G.S., T. I. Pocock, M.A., C. B. Wedd, B.A., F.G.S., and R. L. Sherlock, B.Sc., Assoc. R.C.S., F.G.S., with notes by C. Fox-Strangways, F.G.S. (Explanation of Sheet 125), pp. 199. Price 3*s.*

The Geology of the Country between Newark and Nottingham, by G. W. Lamplugh, F.R.S., W. Gibson, D.Sc., R. L. Sherlock, B.Sc., and W. B. Wright, B.A. (Explanation of Sheet 126), pp. 126. Price 2*s.* 3*d.*

The Geology of the Country around Henley-on-Thames and Wallingford, by A. J. Jukes-Browne, B.A., F.G.S., and H. J. Osborne White, F.G.S. (Explanation of Sheet 254), pp. 113. Price 2*s.*

The Geology of the Country around Andover, by A. J. Jukes-Browne, B.A., F.G.S. Partly from notes by F. J. Bennett, F.G.S., and H. J. Osborne White, F.G.S. (Explanation of Sheet 283), pp. 67. Price 1*s.* 6*d.*

The Geology of the Quantock Hills and of Taunton and Bridgwater, by W. A. E. Ussher, F.G.S. (Explanation of Sheet 295), pp. 109. Price 2*s.*

The Geology of the Country around Oxford, by T. I. Pocock, M.A., with contributions by H. B. Woodward, F.R.S., and G. W. Lamplugh, F.R.S. (Explanation of Special Oxford Sheet), pp. 142. Price 2*s.* 3*d.*

The Water Supply of Kent, by W. Whitaker, B.A., F.R.S., with contributions by H. F. Parsons, M.D., F.G.S., H. R. Mill, D.Sc., LL.D., and J. C. Thresh, M.D., D.Sc., D.Ph. pp. 399. Price 8*s.* 6*d.*

# B. SCOTLAND.

## I.—MAPS.

### (*a*) *One-inch Maps.*

Sheet 60 (Solid Geology).
Sheet 37 (Drift Edition).

### (*b*) *Six-inch Maps of Mining Districts (New Series).*

Edinburgh.—5 N.E., S.E., 9 (and Haddington 14) N.W., S.W., S.E., 11 N.W., S.W., 15 N.W., 18 N.E., 19 N.W., N.E.
Haddington.—9 N.W., N.E., S.W., S.E., 14 N.E.
Linlithgow.—2 S.W. and N.W., S.E., 3 S.W., 6 N.W., S.W., S.E., 10 N.W., S.W.

### (c) *Six-inch Reference Maps.*

The following copies MS., of six-inch sheets have been made from the field copies and deposited in the Office for Public Reference:—

Argyll.—(Islands of Rum and Sanday) 60, 61, 66, 67.
" (Island of Colonsay) 145, 146, 155, 156.
Caithness.—28, 30, 33, 36, 37, 38, 39 and 43, 41, 42, 44.
Inverness.—(Island of Eigg) 71.
Ross.—50.

## II.—MEMOIRS.

Monograph. "The Higher Crustacea of the Carboniferous Rocks of Scotland." By B. N. Peach, LL.D., F.R.S., A.R.S.M. Price 4*s.*

The Geology of the Small Isles of Inverness-shire (Rum, Canna, Eigg, Muck, &c.). Explanation of Sheet 60. By Alfred Harker, M.A., F.R.S., with contributions by G. Barrow, F.G.S. Price 4*s.* 6*d.*

# APPENDIX I.

## On a Boring in the Fullonian and Inferior Oolite at Stowell, Somerset.

By John Pringle.

In 1907 a well and borehole were sunk at Milborne Port, in Somerset. In 1908 Mr. William Phelps, C.E., under whose advice the work has been carried out, kindly offered to place the cores at the disposal of the Geological Survey.

A well had been sunk in 1907 in the Upper Fullers Earth Clay at a short distance below the base of the Forest Marble, and at a depth of 98 feet boring was commenced. Unfortunately, the material obtained from the well was covered by the cores, but it appeared to be grey marly clay. According to Mr. Moore—the engineer in charge of the boring—at depths between 70-80 feet the beds were highly fossiliferous, *Rhynchonella varians* occurring in abundance. No clays resembling the economic Fullers Earth were met with in the boring.

The following table is a record of the beds passed through:—

Well Boring at S.E. side of railway, near Stowell, 1¼ miles W. by S. of Templecombe, 1908. Height above Ordnance Datum about 340 feet. Rest-level of water not known.

| | | Thickness. Ft. | in. | Depth. Ft. | in. |
|---|---|---|---|---|---|
| Upper Fuller's Earth Clay. | Dark grey clay | 98 | 0 | 98 | 0 |
| | Grey earthy limestone | 0 | 8 | 98 | 8 |
| | Dark grey clay | 1 | 4 | 100 | 0 |
| | Dark grey earthy limestone with thin clay partings | 3 | 0 | 103 | 0 |
| | Dark grey clay | 7 | 0 | 110 | 0 |
| | Dark grey earthy limestone | 0 | 8 | 110 | 8 |
| | Dark grey clay | 7 | 4 | 118 | 0 |
| | Grey earthy limestone | 0 | 6 | 118 | 6 |
| | Dark grey clay | 1 | 6 | 120 | 0 |
| Fuller's Earth Rock. | Light grey earthy limestone, full of lamelli-branch fragments, passing down into light grey sandy limestones, slickensided in places, with clayey partings | 35 | 0 | 155 | 0 |
| Lower Fuller's Earth Clay. | Dark greenish grey clay, full of *Ostrea acuminata* | 5 | 0 | 160 | 0 |
| | Light grey earthy limestone | 0 | 9 | 160 | 9 |
| | Dark grey clay | 3 | 3 | 164 | 0 |
| | Grey earthy limestones, with thin clay partings | 6 | 0 | 170 | 0 |
| | Dark clay | 6 | 0 | 176 | 0 |
| | Light grey earthy limestone | 3 | 0 | 179 | 0 |
| | Dark clay | 7 | 0 | 186 | 0 |
| | Grey sandy limestone | 2 | 0 | 188 | 0 |
| | Dark grey clay with thin band of grey earthy limestone | 8 | 0 | 196 | 0 |
| | Grey earthy limestone | 1 | 0 | 197 | 0 |
| | Dark clay with thin earthy limestones | 52 | 0 | 249 | 0 |
| | Grey earthy limestone | 1 | 0 | 250 | 0 |
| | Dark clay | 18 | 0 | 268 | 0 |
| | Grey earthy limestone | 2 | 0 | 270 | 0 |
| | Dark clays, upper beds much veined with calcite, with senna coloured clays at base, crowded with *Astarte* | 62 | 0 | 332 | 0 |
| Inferior Oolite | Hard bluish-grey limestone with *Acanthothyris spinosa* | 18 | 0 | 350 | 0 |

It will be seen that the beds traversed by the boring present the characters usual to the Fullonian in the Sherborne district, and

that in thickness the Upper Fullers Earth Clay and Fullers Earth Rock agree closely with the section at Scale Hill, south-east of Batcombe, where thicknesses of 133 feet and 25 feet were assigned to these divisions by De la Beche.*

The Fullers Earth Rock also agrees closely in character and thickness with the section of beds exposed in the railway cutting at Laycock, north-east of Milborne Port Station, where the following succession was noted by Mr. H. B. Woodward† :—

| | Ft. |
|---|---|
| Grey and brown earthy limestones, rubbly on top, and very fossiliferous ... ... ... ... ... ... ... | 9 |
| Thicker beds of buff earthy limestone, shelly in places ... | 9–10 |
| Dark bluish-grey marls with indurated bands of light bluish-grey earthy limestones ... ... ... ... | 15 |

Immediately underlying the Fullers Earth Rock in the boring are dark grey clays charged with *Ostrea acuminata*, and at a depth of 157 feet a bed almost entirely composed of these shells was passed through; but no other examples were found above or below this horizon. It is interesting to note that the same species of *Ostrea* has been observed elsewhere in clays on the same level. Mr. H. B. Woodward remarks that "West of Cock Inn, Holton, small specimens of *Ostrea acuminata* are abundant in the clays beneath the Fullers Earth Rock,‡ and in a road-cutting leading from Wellow to Upper Baggeridge Farm, there may be seen grey clay with the same *Ostrea*, and this is overlaid by brown earthy and rubbly limestones."§ Mr. John Rhodes, whilst collecting fossils in that district also obtained the same forms in a road leading to New England, east of Milborne Wick, and it is possible that the remarkable outcrops of oyster-bands south of Langton Herring,‖ are on the same horizon. It is hoped, therefore, that the recognition of the restricted range of *Ostrea acuminata* will prove of service to observers in the Fullonian of the district.

Below the *Ostrea acuminata* band at the base of the Fullers Earth Rock, and reposing at the bottom of the boring on a hard bluish-grey limestone, characterised by the abundance of *Acanthothyris spinosa*, is a series of dark-grey clays and thin earthy limestones attaining a thickness of 177 feet. Lithologically they are similar to those always considered to belong to the Lower Fullers Earth, but since so great a thickness has never been recorded in that district, the possibility of the lower part of this division representing some of the zones of the Inferior Oolite immediately suggested itself. Among many badly preserved fossils several ammonites occurred, which were submitted to Mr. S. S. Buckman for examination. His report confirms the suggestion, for below the horizon of *Ostrea acuminata* he recognises evidence for the presence of his Truelli and Zigzag Zones, and probably also the overlying Fusca Zone of the Inferior Oolite. It appears, therefore, that the Lower Fullers Earth Clay must be regarded as equivalent to some of the uppermost zones of the Inferior Oolite. The late Prof. R. Tate believed the whole "Fullers Earth" formation to be of Inferior Oolite age, but the

* *Mem. Geol. Surv.*, vol. i., 1846, p. 280.
† 'The Jurassic Rocks of Britain,' vol. iv. (*Mem. Geol. Surv.*), 1894, p. 236.
‡ *Ibid.*, p. 236. § *Ibid.*, p. 240.
‖ 'The Geology of the Isle of Purbeck and Weymouth' (*Mem. Geol. Surv.*), *1898, p. 5.*

present evidence supports the view that a dividing line between the Inferior and Great Oolite Series should be drawn about the top of the Lower Fullers Earth Clay. Whether the band with *Ostrea acuminata* should be included with the lower or upper series is uncertain, but the specimens from it are placed under the heading of Inferior Oolite in the tabular list given below.

The following is a list of fossils from the cores. With the exception of the ammonites, they have been named by myself, with occasional help from Dr. Kitchin.

| Genera and Species. | Great Oolite Series. | | Inferior Oolite Series. | |
|---|---|---|---|---|
| | Upper Fullers Earth Clay. | Fullers Earth Rock. | Lower Fullers Earth Clay. | "Spinosa" Limestone. |
| Serpula sp. ... ... ... ... | — | × | × | |
| Acanthothyris spinosa (*Schloth.*) ... | — | — | — | × |
| Ornithella ornithocephala (*J. Sow.*) ... | — | × | | |
| Rhynchonella varians (*Schloth.*), *var.* smithi *Dav.* ... ... ... ... | × | × | × | |
| Terebratula nunneyensis *S. Buckm.* ... | — | × | | |
| Terebratula sp. ... ... ... ... | × | | | |
| Astarte elegans *J. Sow.* ... ... ... | — | — | × | |
| Cardium ? ... ... ... ... | — | × | | |
| Ceromya ? ... ... ... ... | — | × | | |
| Goniomya sp. ... ... ... ... | — | — | × | |
| Grammatodon sp. ... ... ... | — | — | × | |
| Lima (Plagiostoma) sp. ... ... | × | | | |
| Lima sp. ... ... ... ... ... | — | — | × | |
| Modiola gibbosa *J. Sow.* ... ... | × | × | | |
| „ sowerbyana (*d'Orb.*) ... ... | — | × | | |
| Nuculana sp. ... ... ... ... | — | — | × | |
| Opis sp. ... ... ... ... ... | × | | | |
| Ostrea acuminata *J. Sow.* ... ... | — | — | × | |
| „ sowerbyi *Morris and Lycett* ... | — | × | | |
| „ subrugulosa *Morris and Lycett* | — | — | × | |
| „ sp. [large] ... ... ... | — | — | × | |
| Pecten (Chlamys) articulatus (*Schloth.*) | — | — | × | |
| „ (Syncyclonema) demissus *Phill.* | × | × | × | |
| „ (Camptonectes) lens? *J. Sow.* | × | | | |
| Pholadomya deltoidea (*J. Sow.*) ... | × | | | |
| „ sp. ... ... ... ... | — | — | × | |
| Pinna sp.... ... ... ... ... | — | × | | |
| Pleuromya *cf.* recurva (*Phill.*) ... | × | | | |
| „ sp. ... ... ... ... | × | — | × | |
| Pseudomonotis sp. ... ... ... | — | — | × | |
| Trapezium ? *cf.* caudatum (*Lyc.*) ... | × | | | |
| Trigonia costata *J. Sow.* ... ... | — | — | × | |
| Unicardium ? ... ... ... ... | — | — | × | |
| Amberleya sp. ... ... ... ... | — | × | | |
| Oecotraustes? [or Strigoceras ?] ... | — | × | | |
| Oppelia subradiata (*d'Orb.*) [pars] ... | — | — | × | |
| Parkinsonia densicosta (*Quenst.*) ... | — | — | × | |
| Perisphinctes sp. ... ... ... | — | × | | |
| Zigzagiceras procerum (*Seebach*) ... | — | — | × | |
| „ *cf.* pseudoprocerum (*S. Buckm.*) ... ... | — | — | × | |
| „ zigzag (*d'Orb.*) ... ... | — | — | × | |
| Belemnites *cf.* parallelus *Phill.* ... | — | × | | |
| „ sp. ... ... ... ... | — | × | | |
| Eryma sp. ... ... ... ... | — | — | × | |

Regarding the *Perisphinctes* from the Fullers Earth Rock, Mr. Buckman in a brief note compares it with Oppel's *Ammonites funatus* (Quenstedt's *A. triplicatus*), which is said to be Callovian. He states that a form resembling the German species occurs in the Garantiana Zone of Sherborne, but that this specimen from Stowell is quite unlike any known fossil from the Fullers Earth Rock. There is no reason to doubt that the depth of this fossil in the boring has been correctly noted; the occurrence, therefore, of such a form at this horizon is probably a new record.

# APPENDIX II.

## On the Stratigraphical Position of the Achanarras Fauna in the Old Red Sandstone of Caithness.

By R. G. Carruthers.

The recent work of the Geological Survey in Caithness has thrown much light on the position of the Achanarras fish-fauna in the flagstone series of that county. In the following paper a historical account of geological research in Caithness will not be attempted, but it may be mentioned that in 1858, Sir R. I. Murchison regarded the Old Red rocks of that region as belonging to the Lower, Middle, and Upper divisions of that system.* This view was subsequently controverted by Sir A. Geikie, who, in his well-known paper "On the Old Red Sandstone of Western Europe," published in 1878,† contended that only the Lower and Upper divisions were represented. In recent years, however, Dr. Traquair, on palæontological grounds, has referred the Caithness rocks, exclusive of the Upper Old Red strata, to the Middle division only.

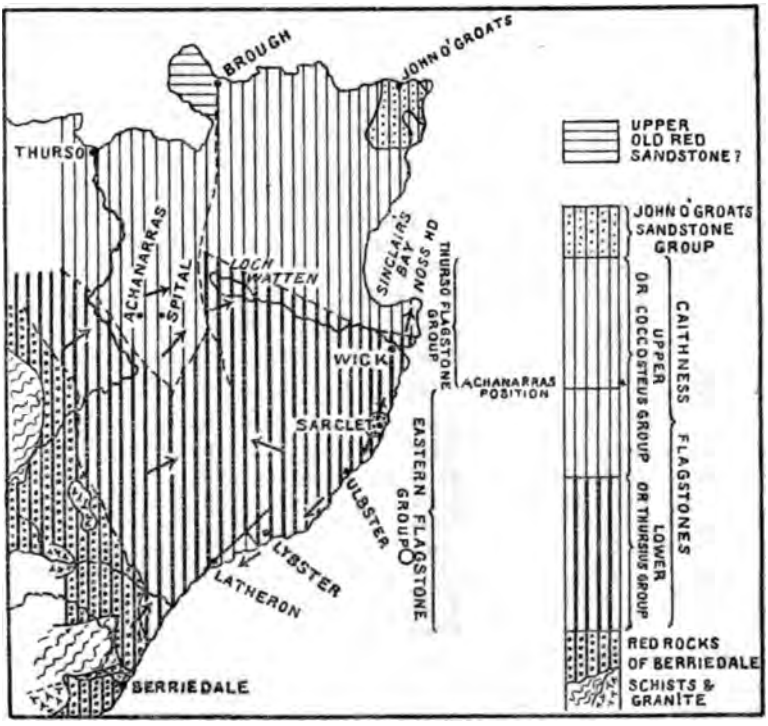


Fig. 3. Geological Sketch-map of Caithness.

There are three prominent sub-divisions of the Middle Old Red Sandstone in Caithness: (1) a basal group of red flags, sandstones,

* *Quart. Jour. Geol. Soc.*, vol. 15, p. 354 (1859).
† *Trans. Roy. Soc. Edin.*, vol. 28, pp. 345–452 (1879).

and conglomerates, largely developed in the south round Berriedale; (2) the Caithness Flagstones proper, covering the greater part of the county; and (3) an uppermost group of red and yellow sandstones (John o' Groats Sandstone Group), found in the north-eastern part of Caithness.

Above the red rocks of Berriedale (1) lie the Caithness Flagstones proper (2) which present two main types of development on the northern and eastern coasts respectively. The flags on the east coast (*Eastern Flagstone Group* of Sir Archibald Geikie) are seen to overlie the red rocks. They form, in the main, a dark weathering series of rough dark-blue or black flags, with intercalated bands of hard grey and yellow sandstone. Occasional bands of smooth splitting "limestone" are met with. Fish remains in this group are practically confined to these "limestone" bands, and are remarkably few in species, although often numerically abundant. In the lower part *Thursius* is by far the commonest form, but in the higher beds north of Wick and south of Lybster, *Coccosteus* appears as a characteristic fossil.

In the northern parts of Caithness the flagstones are of quite a different character. They consist of grey flags, weathering in delicate shades of pale blue, green, and buff colour, and comprise the *Thurso* or *Northern Flagstone Group* of Sir Archibald Geikie. In these Thurso beds, "limestone" bands, like those in the Eastern Flagstones, are very rare, but on the other hand the flags themselves are usually slightly calcareous. Bands and nodules of bituminous matter are common. In addition, the fish remains, instead of occurring only in smooth "limestone" bands, as they do in the Eastern Group, are here met with in rough and smooth flags alike, and are abundant both in numbers and in species. The genus *Coccosteus* is one of the commonest forms. The well-known specimens of Caithness fishes, so often found in museums, nearly all come from these Thurso beds, and so also do the flagstones of commercial value (Thurso, Banniskirk, Spital, &c.).*

The Thurso Flagstones pass upwards into the John o' Groats Sandstone Group, a series of red and yellow sandstones developed in the north-eastern part of the county, and forming the highest members of the Middle Old Red Sandstone, definitely known.

Reference must now be made to some of the important contributions to our knowledge of the fish fauna of the Middle Old Red Sandstone of Caithness, by Dr. Traquair.† He showed that a band of calcareous flagstone found in the small quarry of Achanarras, about a mile west of Spital, contained a remarkable fish fauna. Amongst many species found elsewhere (especially in the Thurso Flagstones), there occurred other fishes which, in

* The exact limits and relations of the Thurso group and of the Eastern Flagstone Group were not defined by Sir Archibald Geikie. These two divisions however are retained for the purposes of this paper, as they conveniently designate the two main lithological types set forth in the above description.

† (1.) "On the Fossil Fishes found at Achanarras Quarry, Caithness." *Ann. and Mag. Nat. Hist.*, 6th ser., vol. vi., p. 479 (1890). (2.) "Achanarras Revisited." *Proc. Roy. Phys. Soc., Edin.*, vol. xii., p. 279 (1894.)

Caithness, were peculiar to this locality. Of these special forms one, *Palæospondylus gunni*, was unique, and of the greatest zoological interest, while the rest had been found at horizons low down in the Old Red Sandstone of the Moray Firth and Orkney, but never before in Caithness.

Dr. Traquair considered that the general faunal assemblage at Achanarras indicated a lower horizon than any of the well-known fossil localities in the Caithness Flags that he was acquainted with, but refrained from any conclusion as to its position in the general stratigraphical succession. He eventually made out three fish faunas in the Caithness rocks, viz., an upper one from the John o' Groats Sandstones, the middle one from the Thurso Group, and the third and lowest, that of Achanarras. These three faunas were subsequently found in the same order in the Orkneys by Dr. Flett, the one correlated with Achanarras (from the Stromness Beds) occurring low down in the series, and close to the junction with the underlying schist and granite.*

At Sarclet, four and a half miles south of Wick, the basal red beds (Berriedale Series) are brought to the surface along a well-marked anticline. The following order of succession of the strata, between the basal beds of Sarclet and the John o' Groats Sandstones, established on lithological grounds, has been furnished by Dr. Crampton.

1. Sarclet Conglomerate and sandstone 600 feet.
2. Ulbster and Iresgoe mudstones and sandstones 1,500 feet.
3. Upper conglomerate 50 feet.
4. Helman Head and Clyth group 2,500 feet. Fragments of *Thursius*.
5. Red Beds of Brough and Hillhead, 1,000 feet.
6. Wick Beds, 1,500 feet. *Thursius macrolepidotus*, *Dipterus*, and *Osteolepis*.
   These beds (1 to 6) form the coast line to Wick and Lybster on the north and south limbs respectively of the Sarclet anticline.
7. Papigoe Beds.
   The change from coarse dark flagstones to soft pale calcareous flags of Thurso type takes place in this group, but the black slates and limestones of lower horizons persist as high up as the Field Beds. *Thursius macrolepidotus*, *Coccosteus decipiens*, *Dipterus macropterus*.
8. Field Beds.
   *Dipterus valenciennesi*, *Coccosteus decipiens*, *Thursius*.
9. Ackergill Beds with black bituminous bands with *Glyptolepis paucidens*, *Coccosteus minor*. At Keiss, Ackergill, and Freswick.
10. Castle Sinclair Beds occupying most of the cliffs between Staxigoe and Freswick. *Thursius pholidotus*, *Coccosteus decipiens*, *Dipterus valenciennesi*, *Glyptolepis paucidens*, *Homosteus milleri*.
11. Noss Beds with *Coccosteus*.
12. Mey flags, with *Homosteus milleri*, *Glyptolepis paucidens*, *Thursius pholidotus*, *Coccosteus minor*, *Microbrachius dicki*, &c.
13. John o' Groats Sandstone.

The lithological characters of these groups have been given in Summary of Progress for 1906, p. 86, and in the Summary for 1908, p. 61.

The section which has furnished definite evidence regarding the fish fauna of Achanarras occurs on the east coast, on the south limb of the Sarclet anticline, and it fortunately happens that here the sequence upwards from the basal red rocks is clear and practically continuous.

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* *Trans. Roy. Soc., Edin.*, vol. xxxix., p. 383 (1898).

If a traverse be made of this coast section from Sarclet southwards, the various groups up to the Wick Beds (No. 6 in the foregoing table) are found in normal sequence as far as Lybster Bay. South of Lybster the ascending succession still continues, and dark weathering flags of the Wick type are found until about a mile south of the village, where a band of hard blue "limestone" is met with. This "limestone" closely resembles those found above the Wick Beds on the north side of the anticline, at Papigoe, and like the Papigoe "limestone," it contains *Coccosteus*, this being the first record of the genus in the upward succession from the basal rocks at Sarclet.

This "*Coccosteus*" limestone is overlain by a great thickness of thin bedded dark flagstones. Although a few beds have a pale colour, the general tint of the weathering is still dark blue or dark grey. Fish remains (*Coccosteus*, *Thursius*, and Acanthodians) in these beds are still confined to "limestone" bands, and the general appearance of the series continues to be of "Eastern Flagstone" type. Overlying this dark weathering series is a group of quite a different aspect, strongly recalling the Thurso or "Northern Flagstone" Group, especially as developed between Spital and the Brough Fault.

The flags weather in delicate shades of pale blue, green, and buff. Fish fragments (especially of *Coccosteus*) occur throughout. Bands of highly bituminous flag are met with, and small pellets of bituminous matter often cover large surfaces. In addition there are several bands of concretionary red and yellow sandstone, as in the Ackergill Beds at Sinclair's Bay. At the base of this group, where these blue flags pass into the underlying dark weathering series, a "limestone" band was found from which Mr. Tait has obtained a characteristic assemblage of the Achanarras fishes (see p. 92). This "limestone" (which will be referred to as the Niand bed, from the neighbouring farmhouse) also possesses the peculiar lithological characters of that at Achanarras*, and is of importance, apart from a palæontological aspect, since it marks a great change in the character of the flagstones.

The thickness of strata of Eastern Flagstone type, from the basal beds at Sarclet up to the Niand limestone is about 10,400 feet, while of the overlying Thurso type at least 1,200 feet are seen before the succession is brought to a close by the great Latheron Fault.†

In concluding this short account of the eastern coast section, attention is drawn to the fact that the flagstones met with admit of two broad palæontological divisions. If a line be drawn at the top of the Wick Flags, all the beds below that line may be said to form a Lower Group, characterised by the presence of the genus *Thursius*. Above the Wick Flags, however, the genus *Coccosteus* suddenly appears, and remains as a conspicuous fossil in all the higher beds. *Coccosteus* is chosen as the index to the upper division, not only on account of its relative abundance, but also because the cephalic plates, covered with their characteristic

* See Dr. Traquair's careful description, *loc. cit.* (1), p. 282.
† "Summary of Progress" for 1907 (*Mem. Geol. Surv.*), p. 90.

pustules, can be readily recognised in the field from the merest fragments. To these two divisions and their distribution over Caithness, reference will again be made.

It is important to notice that the same general relations of the strata are seen at Achanarras itself as at Niand (see map). The strata round Achanarras dip gently to the east and north-east. The flags overlying the limestone at Achanarras may be seen in numerous quarries between that place and the line of the Brough Fault, and these flags all belong to the pale-weathering Thurso Group. The great quarries at Spital are opened out in flags of this type, and from the field evidence the beds worked there must lie but a short distance above the Achanarras "limestone."

But on the other hand the beds underlying the "limestone" worked at Achanarras, as seen in stream sections to the south and west, are of the dark-weathering "Eastern Flagstone" type, just as they are below the Niand bed in the coast sections south of Lybster, and further in the still lower flags two miles to the west, at Westerdale, a "limestone" was quarried which yielded only "*Thursius*," and so presumably belongs to the Lower or *Thursius* division of the Flagstones.

It was owing to the remarkable similarity of the strata on the coast section between Lybster and Latheron to those round Achanarras, and the discovery that the limestone at Achanarras lay at the base of the Thurso Group, that a special examination was made of the Niand bed occurring on the coast section at the base of the Thurso type of flagstones.

From the foregoing evidence it is inferred that the Achanarras fauna occurs at the base of the Thurso Group, and therefore at the junction of the two main lithological divisions of the flagstones, *i.e.*, the Thurso and Eastern Flagstone Groups. This peculiar fauna lies accordingly at a comparatively high level in the Caithness Old Red Sandstone and considerably above the junction of the *Thursius* and *Coccosteus* divisions of the Flagstones.

Dr. Horne points out that this conclusion has an important bearing on the interpretation of the Moray Firth area. As already indicated, Dr. Traquair has found that the fauna of the well-known fish beds of the Orcadian series of the Moray Firth, contains many of the species peculiar to Achanarras. The detailed mapping of that region by the Geological Survey shows that the fish beds occur there near the base of the Orcadian series. If the Moray Firth fish-beds are to be correlated with those of Achanarras, then in this district a great overlap must occur, and the equivalents of the greater part of the Caithness Flagstones are missing. It is interesting to note that this conclusion, based on the recent detailed mapping of the district, entirely supports the views of Sir Archibald Geikie regarding this overlap, so ably expressed in his memoir.*

The accompanying sketch map of Caithness is based on recent Survey work, and includes many observations made by Dr. Peach, Dr. Horne, and Dr. Crampton. Regarding the distribution of

* A. Geikie, *loc. cit.*, pp. 446–448.

the two palæontological groups in the Caithness Flagstones, it will be noticed that, excepting the little strip of the Upper division on the coast near Latheron, the southern part of the county is entirely occupied by the Lower, or *Thursius* group. On the east side of the Brough fault, although a large number of fossil bands have been met with, it is not till we get north of Loch Watten that the genus *Coccosteus* is recorded. On the west side of the fault, however, the *Coccosteus* beds extend further south. The boundaries of these two groups on the map brings out the fact that in the centre of the county the throw of this important fault is still considerable, and is in the same direction as on the north coast at Brough.

*Summary.*

(1.) An almost unbroken succession of strata is found on the east coast between Sarclet and Latheron. Both the Thurso and Eastern Flagstone Groups of Sir Archibald Geikie (as here defined) occur on this coast section and are conformable to one another, the Thurso Group being the higher of the two.

(2.) At the base of the Thurso Group the Achanarras fauna is found. Its position is therefore comparatively high up in the general sequence, and it also coincides with a great change in the character of the flagstones.

(3.) It is suggested that in the Moray Firth area a large overlap is present, and the equivalents of the red rocks of Berriedale and of a large part of the Caithness Flagstones are missing.

(4.) The Caithness flagstones are divided into two palæontological Groups, an Upper, or *Coccosteus* Group, and a Lower, or *Thursius* Group.

(5.) The distribution of these two groups shows that in the centre of the county the throw of the Brough Fault is still considerable, and maintains the same direction as at Brough itself.

*Note on the Fossil Fishes from the Niand limestone, one-eighth of a mile S.W. of the mouth of the Forse Burn. By Dr. R. H. Traquair, F.R.S., F.G.S.*

Among the palæontological finds made by the Geological Survey during the past year in Caithness none are more interesting than the fish remains collected by Mr. Tait from the above-named locality. The list is as follows:—

*Palæospondylus gunni*, Traq.
*Cheiracanthus*, sp.
*Mesacanthus*, sp.
Acanthodian undet.
*Pterichthys milleri*, Agass.
„ *productus*, Agass.
*Glyptolepis paucidens* (Agass.)
*Dipterus valenciennesii*, Sedgw. and Murch.
*Coccosteus decipiens*, Agass.

In the first place, the remarkable and still problematic vertebrate organism, *Palæospondylus gunni*, hitherto confined to Achanarras, has now been found for the first time at a new locality, viz., at Niand, near the mouth of the Forse Burn, on

the east coast. It may therefore be well to glance at the Achanarras list for the purpose of determining whether any further points of special resemblance between the fish faunæ of the two localities may be apparent. The following is the list of fishes found at Achanarras corrected up to the present date:—

*Palæospondylus gunni*, Traquair
*Diplacanthus striatus*, Agassiz
„ *tenuistriatus*, Traquair
*Rhadinacanthus longispinus* (Agass.)
*Mesacanthus*, sp.
*Cheiracanthus murchisoni*, Agassiz
*Pterichthys milleri*, Agassiz
„ *productus*, Agassiz
*Glyptolepis paucidens* (Agass.)
*Osteolepis macrolepidotus*, Agassiz
*Coccosteus decipiens*, Agassiz
*Homosteus milleri*, Traquair
*Dipterus valenciennesii*, Sedgw. and Murch.
*Cheirolepis trailli*, Agassiz

It will now be remembered that fifteen years ago I pointed out that the fish fauna of Achanarras was peculiar in the possession —apart from *Palæospondylus gunni*—of certain genera and species, such as *Pterichthys milleri* and *Pt. productus* (the latter now including *Pt. oblongus*), *Osteolepis macrolepidotus* and *Cheirolepis trailli*, not found elsewhere in the Caithness area, but abundant in the Orcadian nodule beds of the Moray Firth and in the Stromness district of Orkney, a circumstance which must also be taken into account in comparing the fishes of the Niand limestone with those of Achanarras. And we accordingly find that although *Osteolepis macrolepidotus* and *Cheirolepis trailli* have not yet been obtained from the Niand bed, the two species of *Pterichthys* have been collected from it, while the other nameable species, *Glyptolepis paucidens*, *Dipterus valenciennesii*, and *Coccosteus decipiens* are well known at Achanarras, though certainly not peculiar to that locality or horizon.

The list from the Niand bed is smaller than that from Achanarras, but giving due weight to the species which do occur, we may, I think, safely assume that the bed in question represents the Achanarras horizon.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

OF

# GREAT BRITAIN

AND THE

# MUSEUM OF PRACTICAL GEOLOGY

FOR

# 1909.

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# SUMMARY OF PROGRESS

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# GEOLOGICAL SURVEY

AND

# MUSEUM

FOR 1909.

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## I.—*INTRODUCTION.*

In England and Wales the primary six-inch Survey has been continued in Devonshire, Pembrokeshire, Nottinghamshire and Derbyshire.

In Devonshire a considerable area of Dartmoor granite and of the adjacent sediments around Tavistock on the west and Ashburton on the east have been mapped. In Pembrokeshire the survey of the South Wales Coalfield has been completed. In the Midland Counties the mapping of the exposed part of the Nottinghamshire and Derbyshire Coalfield and of a considerable tract to the east has been carried northwards to the Yorkshire boundary, where a junction has been effected with the old work carried out on the six-inch scale by the late Professor Green. The whole of the exposed part and a considerable portion of the concealed part of the great Yorkshire, Derbyshire and Nottinghamshire Coalfield has now been surveyed on the six-inch scale.

In Scotland the original survey of the Highlands has been carried on in Mull and South Morvern in the West Highland District, and in parts of Sutherlandshire, Perthshire, Inverness-shire and Argyll-shire in the North and Central Highland Districts. The revision of the Carboniferous areas in the Midland Valley has been continued in the Shotts and Fauldhouse District, and in the Kilbride and Carluke District.

### Pre-Cambrian Rocks and Crystalline Schists.

Highland Schists have been surveyed in South Morvern and in Mull. The mapping of the granite which forms the Ross of Mull has been completed. It extends over some twenty square miles and varies remarkably little in composition or texture except along the junction with the schist. In the central part of the area several large inclusions have been mapped, some of which are two or three hundred yards in length.

Highland metamorphic rocks with associated igneous intrusions have also been mapped in Sutherlandshire, round the two Beinn Griams, and in the neighbourhood of Lairg. The phenomena me[illegible]

with are similar to those already described from adjacent areas. Synthetic gneisses formed by impregnation and *lit par lit* injection of sedimentary schists with granitic material occur in the area examined. Other areas in which crystalline schists have been surveyed lie in Perthshire and Inverness-shire between Lochs Ericht and Garry, between Loch Rannoch and Glen Lyon, and in the neighbourhood of Ben Nevis. The mapping of Ben Nevis has brought out the fact that the lavas forming the summit rest on a basis of crystalline schist which is almost entirely concealed by the surrounding granite of much later date. A special account of this very interesting area is given in Appendix V.

The plutonic complex on the south side of St. Bride's Bay in Pembrokeshire has now been completely surveyed. It is certainly of pre-Llandovery, and probably of pre-Cambrian age. In many respects it resembles the granulitic series of the Lizard. The rocks forming the complex have been much shattered and crushed by the post-Carboniferous earth-movements.

## Lower Palæozoic Rocks.

Small areas of Llandilo and Bala rocks containing characteristic fossils, and also an extensive series of volcanic rocks associated with unfossiliferous quartzites, grits and mudstones, undoubtedly belonging to the Skomer group, have been surveyed in Pembrokeshire. The age of the Skomer rocks has not been definitely fixed, but the balance of evidence points to the Arenig period. These rocks are erroneously represented on the old map as intrusive greenstones.

Representatives of the Upper Llandovery, Wenlock and Ludlow stages have also been met with in Pembrokeshire.

## Devonian Rocks.

In Devonshire rocks of Devonian age have been surveyed between the granite-masses of Dartmoor and Bodmin Moor, and also on the east side of Dartmoor, about Ashburton. The junction between the Culm Measures and the Devonian lies within the area examined, and special efforts have been made to determine, if possible, the original relations of the two groups of rocks. No satisfactory result has been arrived at, for wherever the junction can be most exactly located it proves to be a fault or thrust. The most interesting result of the work in this district has been the recognition of inliers of Upper Devonian rocks in the area represented as Culm Measures on the old map.

In Pembrokeshire Old Red Sandstone rocks have been surveyed on the south side of Milford Haven and in Skokholm Island.

In Scotland Old Red Sandstone rocks have been mapped in East Sutherlandshire. Here as elsewhere in the Highlands they rest on an uneven floor of the older gneisses and schists. The lowest bed is a conglomerate containing rounded, subangular and angular fragments of the local rocks. Numerous fishes have been collected from the Old Red Sandstone of Caithness during the year and determined for us by Dr. Traquair.

## Carboniferous Rocks.

In Devonshire the Culm Measures have been surveyed in the areas already referred to in dealing with the Devonian rocks. Owing to the disturbed nature of the ground the sequence in the Lower Culm has not been clearly established. Radiolarian cherts have been mapped over wide areas on the west side of the Dartmoor granite where they are often found in contact with Upper Devonian rocks; the grits and shales which intervene between these two formations in the Boscastle area being absent here. The highly altered Culm sediments on the west side of Dartmoor have been proved to extend eastwards over the granite and outlying patches, resting on the granite, nearly a mile from its western margin, have been mapped. The low dip of the granite-surface beneath the altered sedimentary rocks on this side is further proved by the great width of the metamorphic aureole.

In Pembrokeshire Millstone Grit and Coal Measures have been followed to the coast of St. Bride's Bay so that the primary six-inch survey of the South Wales Coalfield is now complete.

In the Midland District the survey of the Derbyshire Coalfield has been continued northwards to the county-boundary.

In Scotland the work of revising the original survey has proceeded in the eastern, southern and western portions of the great Lanarkshire Coalfield. In the Shotts and Fauldhouse district on the east the Coal Measures are almost entirely concealed by superficial deposits, but the structure can be made out by reference to the old workings for coal and ironstone and to the more recent bores. No important modifications of the earlier work have been introduced. Further evidence of the step-like form of the upper surfaces of some of the whin sills, described in last year's Summary, has been obtained. In the Carluke district on the south, areas of Carboniferous Limestone and Coal Measures have been revised, and the Main Coal of this district has been definitely identified with the Hurlet seam. In the district of East Kilbride on the west a small area formed of strata belonging to the Middle Limestone group and containing workable coals has been detected in the centre of the basin.

The question of the relation of the Upper Red Barren Measures of Scotland to the productive Coal Measures is of considerable economic importance. It is discussed in Appendix IV., and the conclusion is reached that the evidence on which they have been supposed to be unconformable to the underlying rocks is unsatisfactory.

## Permian and Trias.

The various members of these formations, as they are developed in the Midlands, have been met with during the year in connexion with the survey of the Nottinghamshire and Derbyshire coal-field.

Rocks, presumably of Triassic age, have also been met with in Scotland, in Mull and South Morvern. In the latter locality they consist of a basal breccia composed of subangular fragments of gneiss, succeeded by red marls and white sandstone containing limestone-nodules of cornstone-type. It is pointed out that these cornstones are comparable with the "kankar" of India, and therefore probably throw light on the climatic conditions of this area during early Mesozoic times.

### Jurassic Rocks.

Representatives of the Upper, Middle and Lower Lias, and of the Lower Oolites, have been recognised in the south-eastern part of Mull, and Lower Lias has been encountered in South Morvern.

The Lower Oolites of Mull have yielded a general assemblage of fossils, agreeing very well with that from rocks of the same age in England. Several of Mr. Buckman's subdivisions have been detected.

### Cretaceous Rocks.

A glauconitic sandstone of Upper Cretaceous age has been met with in Mull.

### Tertiary Rocks.

Lavas, breccias and intrusive igneous rocks of Tertiary age have been mapped in the island of Mull. The lavas are for the most part of the usual basaltic character, but acid or sub-acid types have also been observed. The intrusive rocks include an extensive mass of granophyre, numerous basic sheets, inclined towards a central axis in the manner described by Mr. Harker in Skye, and dykes both of "local" and "regional" types.

Special interest attaches to the relation of the granophyre to the bedded basalts in the Salen district. The outer margin of the granophyre is vertical and cuts across successive beds of basalt; but the original upper surface, where it can be observed, is nearly horizontal, the roof being formed of bedded basalt. A curved fault running parallel with the vertical margin and occurring about one mile from it has tilted the lavas, brecciated the granophyre and apparently lowered the roof several hundred feet on the concave or inner side. The fault is crossed by some of the later dykes and must therefore have been produced before the minor intrusions had ceased.

Plateau-forming basalts have also been mapped in South Morvern.

In England the well-known lignites and clays, near Bovey Tracy in Devonshire, have been re-examined with the view if possible of definitely determining their age by means of the fossil plants. Many new species of plants have been found and the balance of evidence is now in favour of referring the deposits to the same period as the lignites of the Rhine which are generally regarded as belonging to the close of the Oligocene period.

### Pleistocene and Recent.

The superficial deposits have been surveyed in all regions where field work has been carried on. Interesting facts bearing on the history of Scotland during the glacial period will be found in those parts of the Summary which relate to Mull and to the eastern parts of the Moor of Rannoch.

Glacial deposits are rare in the areas mapped in Derbyshire and Nottinghamshire, but they have been observed in a few isolated localities and under conditions which show that they must originally have been much more extensive than they are at present.

Relics of the now well-known raised beach and patches of boulder clay containing marine shells have been found in Pembrokeshire.

# II.—FIELD WORK.

## (A.) ENGLAND AND WALES.

Geological surveying was continued in the three districts which have been in hand for some years :—

1. Midland District under Mr. G. W. Lamplugh.
2. Southern District under Mr. C. Reid.
3. South Wales District under Dr. A. Strahan.

All three districts have been completed so far as is contemplated at present.

In addition to the ordinary field-work, Dr. Strahan visited a deep boring for coal at Seascale, in which red sandstone (St. Bees Sandstone) was found to extend to a depth of 2,000 feet without the base being reached.

The results of his examination of the further boring at Stowell are described by Mr. Pringle in Appendix 1. Several borings for coal have been examined by Dr. Gibson, and a new deep boring at Battle has been visited by Mr. Lamplugh. Mr. Barrow has continued his visits to the Bicester railway-cutting.

### 1.—Midland District—Derbyshire and Nottinghamshire.

Mr. G. W. Lamplugh, F.R.S., District Geologist.

Mr. J. B. Hill, R.N.
Mr. W. Gibson, D.Sc.
Mr. C. B. Wedd, B.A.
Mr. B. Smith, M.A.
} Geologists.

By the field-work of the year, the re-survey of the Derbyshire Coalfield on the six-inch scale has been completed up to the Yorkshire border, there joining with the six-inch mapping already done in Yorkshire. In Nottinghamshire the survey of the Permian and Triassic country has been carried northward to the completion of the area in Sheet 113 (Ollerton), which is as far as it is intended to continue this work at present. Toward the end of the field-season Mr. Lamplugh, Mr. Hill and Mr. Smith were chiefly engaged in collecting information respecting the water-supply of Nottinghamshire, especially in that part of the country which has not yet been surveyed on the six-inch scale, and a memoir on the water-supply of the whole county is now being prepared.

The Millstone Grit Series and part of the Lower Coal Measures in the district south-west of Sheffield were mapped by Mr. Wedd; the main part of the Coal Measures south and south-east of Sheffield was surveyed by Dr. Gibson; the work of Mr. Hill included the remaining part of the Middle Coal Measures and the overlying Permian rocks to the eastward; and Mr. Smith's district covered the Keuper country around Tuxford, including the valley of the Trent, in the north-eastern portion of Sheet 113.

#### MILLSTONE GRIT SERIES.

As regards the country south-west of Sheffield, Mr. Wedd reports that the principal structural feature is an anticlinal fold which enters from the east on the south side of Dronfield, and

continues westward by Cowley and Holmesfield to Owler Bar, whence it bends northward and joins the anticlinal elevation of Houndkirk Moor. An anticline that extends westward in the Coal Measures at Norton seems also to continue in the same direction across the southern corner of Yorkshire and to join that of Houndkirk Moor. Thus a horse-shoe shaped fold, elongated in a general east-and-west direction, contains between its two branches the broad synclinal trough of Totley and Dronfield described in the context by Dr. Gibson. Numerous faults, of no great displacement, intersect the district, the majority having a trend between west and north.

In its sequence and character the Millstone Grit Series shows little variation from the conditions described in previous Summaries. The Shale Grits at the base do not appear at the surface within the area surveyed, and little of the Kinderscout Grit is seen. This grit is overlain by a marine shale-bed containing *Glyphioceras* and *Pterinopecten*. A similar bed occurs in the upper part of the succeeding shales, a few feet below the base of the Chatsworth Grit, a band of marine fossils having been noted at intervals at or near this horizon for several miles southward.

The lower part of the Chatsworth or Rivelin Grit, the most conspicuous grit in the neighbourhood of Hathersage and Burbage Moors, is a fine-grained fissile rock which sometimes lies in two distinct beds and is separated by shale from the main part, a thick coarse-grained pebbly grit that everywhere makes a bold escarpment. Further south the fine-grained lower member appears to be homotaxial with beds necessarily included in the Chatsworth Grit, as explained in last year's Summary. On Hathersage Moor these lower beds are extensively represented and are capped by overlying patches of the massive upper grit forming conspicuous hills at Higger Tor and Carl Wark. But a mile further east they are apparently represented by very few feet of similar material, with a greater thickness of shale intervening between them and the main Chatsworth Grit.

The coal overlying the Chatsworth Grit attains a thickness of 3 feet to 4 feet near Ringinglow, where it usually includes a parting of shale. Nodules of pyrites obtained from the coal and the shale above it were formerly used for the manufacture of copperas.

The small fine-grained Longshaw Grit, next above the Chatsworth Grit, makes an unusually bold feature at White Moor, near Longshaw Lodge, and has been quarried there. There is evidence of another thin fine-grained rock between the Longshaw Grit and the Rough Rock. It is not recognisable much further south, but is everywhere present near the Yorkshire border. A small tract of Millstone Grit, lying to the east of Longshaw Lodge and apparently containing both these fine-grained grits, was assigned to the Coal Measures on the old map.

The Rough Rock, in its usual character of a rather coarse and slightly pebbly grit, maintains a continuous escarpment northward to Longshaw Lodge, where it is faulted out. It reappears further east in Blacka Hill, but from there northward it is again cut out by faults for a long distance.

## LOWER COAL MEASURES.

The lowest measures, those below the Alton Coal, along the western margin of the Coalfield were found by Mr. Wedd to be unusually thin near Baslow, but they recover their usual thickness of about 300 feet northward near Dore. At the same time the sandstone-beds increase in number and thickness. Moreover, as they are traced northward some of them lose the silty appearance so characteristic of sandstones in the southern part of the coalfield and assume a more quartzose character with slightly coarser grain; while at Barbrook Still and Brown Edge, Totley Moor, we meet for the first time with a coarse-grained and somewhat pebbly rock resembling the Millstone Grits and of a type common in the Yorkshire Coalfield, at a horizon about half-way between the Rough Rock and the Alton Coal. Thin bands of coarse quartzose rock were exposed recently during sewerage operations in Dore village, at a level some distance above the Alton Coal.

Not many feet below the coarse grit of Brown Edge a black marine shale occurs, with *Gastrioceras carbonarium* and *Pterinopecten papyraceus*, and has been met with at intervals as far northward as the county-boundary; while a single bed of *Carbonicola*, probably the same bed as that present in the southern part of the coalfield, is found at a less distance below the Alton Coal. But the marine bed above mentioned has not been noticed farther south.

Immediately above the coarse rock of Brown Edge the gannister underlying a thin coal is worked for the manufacture of fire-bricks and moulds for steel-casting and chemical works.

The Alton Coal proves to be continuous with the Gannister or Hard Mine of Yorkshire, as anticipated. Its roof of marine shale and its gannister floor, wrought for fire-bricks at Millhouses, is also persistent. About 90 feet above it, the Forty Yards or Hard Bed Band Coal of Yorkshire, with its underlying pot-clay and gannister, can be traced southward through Dore. In that village another small coal with fireclay below, occurs at a somewhat higher horizon, a few feet above the thin beds of coarse quartzose rock previously mentioned.

The thick group of the Wingfield Flagstones, forming a conspicuous feature above some 200 feet of shale, becomes continuous with the Brincliffe Edge Rock (Elland Flags) of Sheffield.

The Kilburn Coal has not been recognised, but may perhaps continue as a four-inch seam at a slightly higher horizon.

The succeeding measures show frequent alternations of fine-grained sandstone and shale for a thickness of 200 to 300 feet. They are followed by a similar group of strata extending upwards to the Silkstone Coal and containing two or three small coal-seams of which the only important one is the Mickley Thin Coal, a thin but good coking seam about 200 feet below the Silkstone.

In the country south and south-east of Sheffield, mapped by Dr. Gibson, the Lower Coal Measures form the cores of the two anticlines already referred to by Mr. Wedd. The one north-east of Sheepbridge is a continuation of the anticline mentioned in the Summary for 1908 (p. 15) as extending in a general north and south direction from Teversal to Whittington Moor. A little south

of Whittington it swerves to the west, and on its emergence from the alluvium of the Drone at Unstone Green it becomes the east and west anticlinal fold of Holmesfield. The steep inclination of the strata on the northern and southern flanks soon brings in the Middle Coal Measnres of the Dronfield and Sheepbridge synclines so that only about 400 feet of Lower Coal Measures are at the surface.

North of Dronfield the second anticline, trending a little south of east, again brings up the Lower Coal Measures in the districts of Norton and Ridgeway. It includes a subsidiary syncline whose axis corresponds with the Moss River.

The Norton-Ridgeway anticline pitches to the east so that the lowest strata crop out to the west, where they are trenched by the River Sheaf down to the horizon of the Alton Coal. The Wingfield Flagstones form the wooded crests of the Sheaf valley and extend northward in a bold escarpment to the Yorkshire border. The overlying measures up to the Silkstone Coal are intersected by the streams flowing eastward off the anticline into the Rother. They contain a few thin seams of coal; and at Ford, a seam, probably one of the Mickley coals, has been exploited to a slight extent upon the supposition that it is the Silkstone Coal. It is still locally considered that seams of good quality and workable thickness exist round Norton and Ford, but the general absence of profitable seams in the Lower Coal Measures of North Derbyshire is opposed to this view.

### MIDDLE COAL MEASURES.

The utility to the geological surveyor of the sandstones of the Middle Coal Measures as guides in the interpretation of geological structure has been noticed in previous Summaries. Of considerable thickness, forming bold physical features, frequently exposed and once extensively quarried, they were found by Dr. Gibson to be conspicuously serviceable in mapping the area to the south and south-east of Sheffield.

The chief sandstones are those associated with the Silkstone Coal, Deep Hard (Parkgate) Coal, and Deep Soft (Flockton) Coal. Less persistent, but locally massive rocks, are the sandstones in connection with the Top Hard (Barnsley) Coal and the High Hazles (Kents Thick) Coal.

The rock occurring at from 50 to 100 feet above the Silkstone Coal, is coarse and strongly false-bedded. It clearly defines the Norton-Ridgeway and Whittington anticlines and is of equal service in tracing the boundaries of the Dronfield syncline.

Resting immediately on the Deep Hard Coal, a massive but more evenly bedded sandstone is conspicuously developed between Birley and Mosborough; south of these places it splits up into two or more bands separated by shale.

The rock (Manor Rock) above the Deep Soft Coal is chiefly confined to the north part of the area, but is recognisable at intervals up to Barrow Hill (Staveley Works). Higher in the sequence, a few yards below the Top Hard Coal, a sandstone (Woodhouse Hill Rock) is extensively quarried at Beighton and

can be traced southward to Renishaw. This appears to be the rock that is exposed in the railway-cutting east of Barrow Hill Station.

The faults generally trend N.E. or N.W. Several can be detected in the escarpments formed by the Silkstone Rock, but none has a large vertical or horizontal displacement.

The chief seams of coal which crop out west of the Rother are, in ascending sequence :—Silkstone, Deep Hard (Parkgate) and Deep Soft (Flockton, Sitwell, Hollingswood). East of the Rother the Top Hard (Barnsley) coal crops out between Killamarsh and Staveley Town, and is extensively worked in several collieries beneath the Magnesian Limestone to the east.

South of the Whittington anticline, an important seam known as the Tupton or Low Main Coal lies between the Silkstone and Deep Hard, but it is either unrepresented or not workable over the area north of the anticline ; and it does not appear to have a Yorkshire equivalent.

### PERMIAN BASEMENT BEDS.

Along the eastern margin of the Coalfield, surveyed by Mr. Hill, the Coal Measures are unconformably overlain by Permian rocks, of which the lowest member is a variable group of thin limestones, clays and sands. These beds have been traced as a narrow band underlying the Magnesian Limestone from Oxcroft to Pebley Pond. From Pebley Pond, however, a valley running eastward in the dolomite tract, and there forming the boundary between Derbyshire and Yorkshire, exposes them as a narrow tongue for upwards of a mile.

In this area the place of the basal breccia appears to have been taken by the "Quicksands." The latter are overlain by clays and thin limestones similar to those described in the tract to the south.*

The Quicksands are well exposed in railway-cuttings which pierce the escarpment, and they have been extensively quarried at Clowne, Barlborough, and to the south of Pebley Pond. Near the surface they generally take the form of a "sand-rock" firm enough to admit of being tunnelled into large chambers, the walls and roofs of which retain the marks of the tools, as may be seen in the pit at Pebley Pond. Occasionally they contain harder bands cemented by calcite, and in places are studded with small rusty-brown nodules. This deposit shows marked false-bedding, and is generally of a yellow colour, but tints of orange and red are not infrequent. It varies considerably in thickness, being only 1 foot 8 inches in the shaft at Shireoaks Colliery, while at Clowne and Pebley Pond it has been worked to a depth of 20 feet. The most southerly point at which the sand is noticed is in a pit west of Clowne.

The upper members of the basement beds consist of grey shale and mudstone containing small plant-fragments, surmounted by thin limestones with shaly partings. Their thickness in the railway-cuttings at Clowne ranges from 12 to 18 feet, but their upper limit is not well defined, as thin shaly partings occur also in the lowest beds of the dolomite.

* 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, p. 17.

The Quicksands have been extensively quarried both for moulding-sand and mortar, while to the north of Barlborough Colliery the clays were formerly utilized for the manufacture of bricks.

### MAGNESIAN LIMESTONE.

This formation occupies the greater part of the tract mapped by Mr. Hill. The description given last year* of the dolomite country south of Creswell applies in a general sense to the northward extension of the Magnesian Limestone up to the Yorkshire border, and especially in regard to the variations in its structure. In the southern tract it was susceptible of a rough threefold division, the central belt being characterised by a high degree of false bedding and doming, while the upper and lower parts show thin-bedded and more regular flaggy structures. These distinctions were reflected in the topography, the central division forming hummocky ground in strong contrast to the smooth features on either flank. Such conditions are prolonged as far north as Whitwell, but beyond that locality the central division loses its distinctive structures, and the physical features due to them disappear.

The dolomite of this district however exhibits some characters not observed in the southern tract, one being the presence of bands thickly studded with pisolitic bodies, the weathering of which has often produced coarse "honeycomb" structures. The "honeycomb" surface is not altogether confined to the pisolitic dolomite, as it appears often to have resulted from irregularities in original deposition. In many bands this has given rise to a partial solution of the matrix, and the rock thus weakened has been to some extent converted into a breccia by the weight of the overlying beds. Such brecciform structures are abundantly represented in the railway-cuttings between Creswell and Clowne.

The upward passage of the dolomite into marls with intercalated bands of dolomite is seen in the railway-cutting to the north-east of Whitwell Station. The main mass of the dolomite also itself sometimes contains thin bands of red shaly material, as, for an example, in the railway-cutting near Hazelmere Farm.

Fossils have only been detected towards the base of the Magnesian Limestone, and consist mainly of the obscure casts of small shells. They may be seen in the Midland railway-cutting to the west of Clowne Station.

In this district the dolomite yields light soils, and the heavy lands sometimes seen on this formation to the south are rare. The rock has been extensively wrought for building-stone, road-metal and lime. Of the numerous quarries the most extensive are those situated immediately east of Barlborough.

### PERMIAN MARL AND SAND.

With the exception of a small area at Huncecroft, which forms part of the main band lying to the east of the Magnesian Limestone, this division, in the area surveyed by Mr. Hill, is represented

* 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, pp. 17–19.

only by isolated patches surrounded by dolomite, and in these, sand predominates largely over clay. The two patches at Red Hill and Belph Moor represent normal outliers, but an extensive tract at Creswell, and a smaller one to the north of Clowne, owe their position to faulting. The fault which lines the valley at Creswell brings the Marl Series on the west against beds deep down in the Magnesian Limestone Series on the east, and, as was recognised by Aveline, the western end of Creswell Crags must be close to the base of the dolomite series.

### BUNTER.

In the Triassic area, a small tract of Bunter Pebble Beds SE. of Clumber was mapped by Mr. Lamplugh, but presented no feature requiring special mention.

### WATERSTONES.

To the east of the valley of the Maun and Meden, Mr. Smith, in mapping the Keuper rocks, observed that a series of thin flaggy stone-beds in the upper part of the Waterstones forms a well-marked escarpment and platform, traceable from near Milton to the short railway-tunnel near Askham. A road-cutting through the escarpment, half-a-mile west of Markham-Clinton, exposes shales and micaceous marls with thin sandstones, some pale and dolomitic, others pink or red. Ripple-marks and salt-pseudomorphs are common, and flattened clay-galls occur in great numbers. Milton village stands upon a similar platform developed at a lower level. Near Markham Moor and Rockley the river-deposits encroach upon the Waterstones to the east, and isolate a small inlier between the main road and Church of West Drayton. The outcrop of the Waterstones is covered by a red loam containing small chips of the stone-beds.

### KEUPER MARLS.

The Keuper Marls mapped this year by Mr. Smith repeat in all particulars the characteristics described in the two previous Summaries. The principal lower skerry belts between Tuxford, East Markham and Askham form a conspicuous though well-dissected plateau with a gentle easterly dip and a prominent westerly-facing scarp. Dolomitic sandstones, once extensively quarried, are still occasionally raised for road-metalling or building purposes, and beneath them there is a belt of good brick-clay.

The Great Northern and Great Central railway-cuttings furnish useful sections and prove the existence of much fibrous gypsum in the above-mentioned skerry belts. At higher horizons in this district west of the Trent very little gypsum is found, and the well-water is consequently of better quality.

Though in this less elevated northern area the higher and more purely siliceous sandstones do not develop such marked features as they do further south, their peculiar lithological character is still unmistakable. Detailed mapping, in fact, has shown that at different horizons the lithology of the marls and skerry belts is

reflected to a marked degree, not only in the soils and surface features, but likewise in the quantity and quality of the well-waters of the villages upon their outcrops.

## Glacial and Post-glacial Deposits.

Most of the area surveyed during the year was found to be devoid of glacial deposits, yet here and there patches of Boulder Clay and Glacial Gravel were observed in situations which indicate that probably no part of the district has escaped glaciation. It is evident, indeed, that since the disappearance of glacial conditions in this district, the country has been deeply eroded, and that the remaining patches of drift represent only a part of the original deposits.

On the high ground south-west of Sheffield, Mr. Wedd discovered a small tract of Boulder Clay at an altitude of 800 to 1,000 feet in an old valley descending from a gap in the Millstone Grit ridges of Houndkirk Moor. The drift, which is exposed in the banks and in the bed of Redcar Brook, is composed of tough grey clay containing many fragments of grit and shale, with others of Carboniferous chert and limestone and of yellow dolomitic limestone—some of the shale and limestone fragments being well striated. A few bits of far-travelled igneous rock were also found.

This Boulder Clay is partly concealed under an ancient flood-wash of sandy clay full of large blocks of Millstone Grit, which descends from the high-lying hollow of Houndkirk Moor, through the gap already mentioned, as a broad lobe and appears to merge at lower elevations into the high-level terrace of coarse gravel bordering the channel of Redcar Brook.

Another high-lying patch of Boulder Clay was noticed by Dr. Gibson on the Yorkshire side of the border, near Fulwood, at an altitude of close upon 700 feet above O.D. It was exposed in a drain-trench alongside the main-road west of the Tramway terminus, and seemed to be made up entirely of local Carboniferous material, including many well-scratched fragments of shale. Drift of this kind would be difficult to detect, in the absence of clear sections, on the Coal Measure shale-country: and its presence was suspected, but not proved, in some localities south of Sheffield. A mass of stratified drift was also noted by Dr. Gibson a mile south of Beighton (6 miles S.E. of Sheffield) on the crest of the Rother valley, where a large pit has been excavated to a depth of over 30 feet in contorted sand with lenticles of coarse gravel and streaks of coaly detritus.

In the Permian tract farther eastward, surveyed by Mr. Hill, the drift is represented only by scattered pebbles in the soil.

In the sandy Bunter country, Mr. Lamplugh noticed a clayey patch which may be Boulder Clay in the woodland where Clumber Park joins Thoresby Park; and there are numerous far-transported boulders, chiefly of Carboniferous rocks, in the neighbourhood of Elkesley. But the best evidence of glaciation in this tract is exhibited in a brickyard adjoining the Great Central Railway near Checkerhouse, half way between Retford and Worksop. The site lies 3 miles beyond the northern boundary of the area actually

surveyed, but deserves particular mention as affording definite proof of the former extension of ice over all the adjacent country. The excavation, now in abeyance, has been worked entirely in drift, consisting of sandy Boulder Clay overlying and intermingled with laminated loam and sand. The whole mass fills a slight hollow on the dip-slope of the Bunter Pebble Beds, at about 130 feet above O.D. The thickness of the Boulder Clay varies in different parts of the pit, up to a maximum of about 12 feet. Boulders, often well-striated, are numerous and range in size up to 3 or 4 feet in diameter. The majority are Magnesian Limestone, of which several varieties are represented; Carboniferous Limestone and sandstone, and Keuper sandstone blocks are present in less number; likewise a few dolerites or basalts; and a single block of quartz-porphyry was found, resembling the St. John's Quartz-felsite of the Lake District. This drift may have been brought into the district from north-west directly across the Carboniferous outcrop, but more probably it has travelled from the north along the lower ground, as the assemblage of boulders suggests that it belongs to the same trail as the Boulder Clay at Balby near Doncaster.

In the Keuper country west of the Trent, Mr. Smith noticed that Bunter pebbles were present in unusual numbers, along with some small blocks of white and yellow sandstone, in the soil about a mile west of Normanton-on-Trent, at 50 to 100 feet above O.D.; and similar pebbles were plentiful at about the same elevation in two places between Darlton and Ragnall. But in the absence of sections it was impossible to determine whether there was actually drift *in situ* at these places. The former glaciation of the district is, however, fairly well established by the presence of boulder-gravel on high ground further north, at Grove near Retford and at Gringley-on-the-Hill, mentioned in the memoir on the Lincoln Sheet (No. 83) of the Old Series Geological Map.

The isolated position of all these patches of drift and their relation to the contours of the surrounding country indicate a very considerable wearing down of the surface in the intervening ground since the glaciation. This conclusion is borne out by the presence of moundy flood-gravels and high terraces along the Maun and Meden valley, referred to in the last Summary, that have now been traced at intervals up to the confluence of the streams to form the River Idle.

The recent low-level alluvium bordering these streams often indicates by its peaty or loamy composition that there has been great diminution in the volume of water discharging down the valleys since the gravels were deposited.

## Alluvium.

In the Keuper country Mr. Smith observed that the small streams flowing to the Trent from Tuxford and Egmanton in a north-easterly and south-easterly direction are bordered by alluvial flats, chiefly of red loam. Where, however, the main dolomitic skerries dip beneath the valley-floors they throw out springs which have often deposited calcareous tufa. Although the dip of the Keuper Marls is slightly south of east, the tufa deposits of Kingshaugh and

Scarthingmoor, and of Moorhouse and Caunton further to the south, lie nearly on a north and south line, the southern valleys being more deeply trenched than those in the north, so that the skerries extend further east before reaching their floors.

Other alluvial strips of stiff loam with fresh-water shells mark the site of once marshy tracts west of High Marnham and Fledborough, where small escarpments of sandstone traversed by narrow valleys obstructed the waters and caused them to spread laterally.

## 2.—Southern District—Cornwall and Devonshire.

Mr. Clement Reid, F.R.S., District Geologist.

*Mr. W. A. E. Ussher.
*Mr. G. Barrow.
Mr. R. L. Sherlock, B.Sc.
Mr. D. A. MacAlister, A.R.S.M.
Mr. Henry Dewey.
Mr. C. N. Bromehead, B.A.
} Geologists.

In the southern district the officers were engaged on the completion of the Dartmoor and Tavistock maps (Sheets 337 and 338) and on certain corrections needed before the hand-coloured published Newton Abbot and Ivybridge maps (Sheets 339 and 349) can be replaced by colour-printed editions.

The geology of this area (except Dartmoor itself) is so confused as to lend itself with difficulty to any verbal description before maps are available. In a general way the normal east-and-west strike of the Palæozoic rocks of Devon and Cornwall prevails; but in the area between the granite intrusions of Dartmoor and Bodmin Moor, the strikes become very irregular; east of Dartmoor no general strike seems traceable. Everywhere folds and overthrust-faults were met with, the latter generally showing very irregular outcrops.

The moot question of the relation of Devonian to Carboniferous must for the present be left open. None of the officers who have been working on the junction during the past year feel confident as to the original relations of the two systems, for wherever the junction can be exactly located it has proved to be a fault or thrust-plane. Nowhere have they been able to find a basal conglomerate where the Culm rests on Devonian rocks; and yet as they travel northward higher and higher Upper Devonian rocks seem to appear directly beneath the Carboniferous series.

### Devonian.

The completion of the mapping of the Devonian rocks which lie to the west of Dartmoor has led to the discovery of a number of small inliers brought up by folding and faulting in the Culm Measure area. It is possible that other similar inliers may occur still further north; but the work has been carried sufficiently far into the Holsworthy sheet (323) to make the survey of the Devonian area practically complete.

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* Part of the year. *See* footnote p. 18.

One striking point comes out in the study of these inliers; those towards the north-east seem to represent a horizon slightly higher than that of South Petherwin; in fact though their small fauna is undoubtedly Upper Devonian, each inlier yields new and undescribed species. The lithological character of these inliers is also unlike that of the Upper Devonian further south. Unfortunately the bad state of the South Petherwin sections (the best quarry being now used as a receptacle for the town-refuse of Launceston) made it impossible to add to the Petherwin fauna, except for one trilobite, found many years ago by Mr. C. H. Peter, presented by him to the Geological Survey, and described by Dr. Ivor Thomas as *Proetus dunhevidensis*.

The Devonian inliers now for the first time placed on the map of the Geological Survey commence on the west with one at Yeolmbridge, two miles north of Launceston. The fossils from this were however described as Devonian by Phillips as far back as 1841, but the inlier was never mapped. Mr. Reid finds that the Devonian rocks consist of hard greenish or grey platy slate, formerly worked for flagstones, contorted in S-shaped folds. In these slates occurs a band of clay-ironstone nodules, which yields almost all the fossils. Fragments of *Phacops* are particularly abundant. The inlier extends for a mile along the bottom of the valley of the Ottery; it is surrounded on the west by hard black slates, which apparently represent the marine Culm shales of Launceston, whilst at its eastern end it is dominated by crags of massive Culm grit. The junction is nowhere actually visible, but the fact that it runs almost horizontally above rocks which are sharply folded, leaves the impression that we are dealing with a low-hade thrust-plane, neither the true top of the Devonian nor bottom of the Culm being represented.

Another Devonian inlier about two miles long was mapped by Messrs. Bromehead and Sherlock between the Tamar and Lifton. Here again the older rocks are in contact with different parts of the Culm series, for in some places this inlier is bordered by shales, in others by radiolarian chert. The Devonian rocks themselves are peculiar, consisting of black slates, often full of fossils, and containing a thin seam of volcanic lapilli. The few small exposures have yielded various Upper Devonian species, including *Clymenia undulata* and *Entomis serratostriata*; but an equal number of forms appear to be new, *e.g.*, a smooth ostracod, a *Trimerocephalus*, two species of *Orthis*, &c. Perhaps the hard black shales mentioned above as occurring at the west end of the Yeolmbridge inlier may be these black shales, though no fossils could there be found.

In the Brentor area Mr. Sherlock discovered a number of small Devonian inliers and at South Brentor *Entomis serratostriata* was collected in the tip-heap of a quarry, which yields also volcanic lapilli.

On the east side of Dartmoor Mr. Barrow found the Devonian rocks around Holne to consist mainly of pale-grey and greenish-grey soft slates in which *Spirifer verneueli* is not uncommon. These pale slates cover a large area, and are succeeded by much darker slates, probably slightly higher in the series, and perhaps equivalent

to the black slates of Lifton, above described. The boundary between the Devonian and Culm here also is neither an unconformity nor a normal fault, for the Devonian slates overlie the Culm rocks. The dip of the junction-plane is always comparatively low, and close to it the beds are permeated by movement-planes, suggesting that this junction is a low-hade thrust.

## Culm Measures.

The disturbed nature of the ground mapped during the past season renders it difficult to make sure of the succession. We are still uncertain whether some of the thick grits belong to the so-called Middle Culm, or whether they are merely more massive expansions of the grits known to occur in the lower or marine divisions. Radiolarian cherts, which seem generally to occur several hundred feet up in the Lower Culm, are so commonly found also in contact with Devonian rocks, that it is difficult to be certain whether there is in reality only one chert, or whether a second horizon of silicified shale occurs lower down. The basal Culm, immediately in contact with the Devonian slate, may be silicified immediately above a thrust plane, forming a cherty rock which is not always on the same horizon. Radiolarian cherts have been mapped over a wide area in the northern half of the Tavistock map; but the greater part of the exposures certainly belong to a single sheet repeated again and again by folds and thrusts. It seems to be only in the district between Launceston, Callington and Lewannick that a lower horizon of chert may come in.

## Granite.

Mr. MacAlister mapped on the western flank of Dartmoor a series of outlying patches of contact-altered Carboniferous sediments, lying on the granite nearly a mile within its margin. The principal patches discovered are situated almost one and a quarter miles apart. The more northerly outlier occurs between Hare Tor and Sharp Tor at an elevation of over 1,600 feet; whilst the more southerly can be seen on the north of Standon Hill at an elevation of nearly 1,500 feet. Between these outliers a very small patch of highly-altered greenstone-fragments is to be seen on the top of the west side of Tavy Cleave at an elevation of nearly 1,500 feet. The outliers and the long strip of sediments which extends over the granite eastward to Cocks Hill, prove that the general slope of the original granite-surface here varies from about 23° to 32°, and in places may have been much less. The small angle of the slope no doubt accounts for the fact that the metamorphic aureole near Peter Tavy and Mary Tavy attains the exceptional width of nearly four miles.

The granite of Dartmoor has been described so often that we will only draw attention to one or two points. Though variable in texture and composition, it has certain characteristics which distinguish it from the masses further west. It is essentially a black-mica granite with schorl occurring as a plentiful original constituent, not mainly in the altered part. Some parts are fine

and others coarse ; but the two types are so intermixed that it has been found impossible to map them separately. Pegmatite veins also occur.

The metamorphic aureole is well developed in the Dart Valley, where Mr. Barrow finds that in many cases the rocks no longer possess the schistose structure characteristic of Cornwall and indeed are sometimes entirely free from foliation. About Luesdon the rocks in contact with the granite are exceptionally well exposed and consist in part of massive cordierite-hornfels, in which the distinctive mineral is perfectly fresh.

At Tredown, near Kelly, and also at Chipshop, Lamerton, killas has been found by Mr. Sherlock spotted with chloritoid. This rare metamorphic mineral has not previously been recorded from Devon.

## Tertiary.

Whilst the Memoir to accompany the Teignmouth map was in preparation, Mr. Reid took the opportunity to re-examine the Bovey Beds, in order if possible to settle their true age. It will be remembered that these lignites and clays, on the evidence of their contained plants, were referred by Heer to the Miocene period, he correlating them with the Aquitanian of France and with the Hamstead Beds of the Isle of Wight. They therefore appear as Miocene on the old edition of the Geological Survey Map. Later, Mr. Starkie Gardner stated that their flora corresponded with that of the Bournemouth beds (Middle Eocene) and they were therefore coloured as Eocene on the more recent maps. Most of the Bournemouth plants, however, are still unpublished.

Much new material was obtained from the Bovey pit (though the lower parts are under water), and the Heathfield pit was also examined by Mr. and Mrs. Reid, who used new methods in order to extract larger quantities of the seeds in a determinable state.

In the middle of the Heathfield pit a boring was made some years since to a total depth of 526 feet from the surface, and Messrs. Candy & Co. have obligingly let us have portions of the cores for examination. Though this examination is still unfinished it is sufficiently advanced to show that this great thickness of strata all belongs to a single formation, for at a depth of about 500 feet we have obtained seeds of two of the characteristic plants, *Sequoia couttsiae* and *Carpolithes boveyanus*. Unfortunately the plants, through long keeping and decomposition of the pyrites in the cores, are usually much injured.

The examination of the Bovey flora is still incomplete, but a considerable number of additional species have been found and determined. They are nearly all forms belonging to the lignites of the Rhine ; indeed, the resemblance to the flora of these lignites (occurring in the same latitude) is so close that we need have no hesitation in referring them to the same period, generally classed as the close of the Oligocene. The resemblance to the Aquitanian beds of France, generally considered to belong to the same stage, is slighter ; but the French deposits occur several degrees further south, and were surrounded by rocks which would produce soil of a quite different character. Some French writers class the Aquitanian as the base of the Miocene.

Heer's correlation with the continental deposits seems to have been perfectly correct; though the Hamstead Beds are now placed lower in the series, in the Middle Oligocene. Thus the Bovey Beds seem to fill a gap in the British sequence.

The most abundant of the Bovey seeds belong to several species of *Nyssa*, six species occurring, including the characteristic Rhine Valley *Nyssa europaea*, *N. obovata*, *N. ornithobroma*, and *N. vertumni*; the other two are confined to Bovey, but are only represented by the original specimens figured by Heer, now badly preserved. An unrecorded *Magnolia*, and the only palm (a *Daemonorops*) are also identical with Rhine species. Climbing plants seem to have been abundant. We have not only this rotang-palm, but three vines, and a *Rubus* very close to our modern blackberry. This mingling of the out-going warm-temperate with incoming northern forms is probably due to the proximity of Dartmoor, which rises sharply above the Bovey Basin; but it is also a characteristic of the close of the Oligocene period. The absence or great scarcity of sedges, grasses and mosses make it difficult to call the Bovey Beds Miocene, in the modern sense of the term.

The Bovey flora, so far as examined, seems to be essentially the flora of the granite-ravines, with the admixture of a very few aquatic forms, a water-lily, pond-weed, *Stratiotes*, *Sagittaria* and an aquatic arum (*Calla*) being the only ones found. Marsh-plants are exceedingly rare, the swamp cypress, *Taxodium distichum*, previously unrecorded, being now represented by a single scale of the highly sculptured cone.

*Sequoia couttsiae*, which Mr. Gardner at one time thought to be a swamp *Athrotaxis*, is a true *Sequoia*, abundant material now having been obtained for the study of the anatomy of the cone and leaf. It probably grew, like the *Nyssa*, in the granite ravines; for though the lignites at Bovey, close to the border, are full of its shed twigs and cones, at Heathfield, near the centre of the lake, it is very rare. As far as one can judge by the lignite now visible, it was probably a tree of moderate size; though large logs would not easily be washed out of the narrow ravines, and this may account for the small size of the fossil tree, compared with the gigantic *Wellingtonia* of California.

### 3. South Wales District—Pembrokeshire.

Mr. G. Barrow, District Geologist.*
Mr. T. C. Cantrill, B.Sc.
Mr. E. E. L. Dixon, B.Sc.
Mr. H. H. Thomas, M.A., B.Sc.
Mr. O. T. Jones, M.A., B.Sc.
} Geologists.

The field-work in 1909 lay among the Silurian and igneous rocks of Marloes, in the igneous complex south of St. Bride's Bay, and in the Carboniferous tract of Nolton and Broadhaven on St. Bride's

* Mr. Barrow having been appointed District Geologist during 1909 was placed in charge of the South Wales District so far as regarded administrative matters. The direction of the work during this the last year of field-work in the district, and the editing of the remaining publications, remained in the hands of Dr. Strahan.

Bay. The Old Red Sandstone of Skokholm Island also was examined, and the surveying of the tract south of Milford Haven was completed. The re-survey of South Wales on the six-inch scale has thus been brought to a conclusion, so far as regards the one-inch sheets which illustrate the coal-fields.

The formations which are represented in the area surveyed during the year range in age from pre-Cambrian to Carboniferous, and include three or more series of igneous rocks. Among these mention may be made of a lava of Upper Llandovery age in Marloes Bay, a great series of acid, intermediate and basic lava-flows, probably of Arenig age, at Wooltack and on Skomer Island, and the igneous complex which bounds the coalfield on the south, and which is probably of pre-Cambrian age.

### PRE-CAMBRIAN ROCKS (SUPPOSED).

The chief facts of interest observed by Mr. Jones have been those obtained from his examination of the extensive coast-sections in the plutonic rocks referred to as the Johnston Series in a previous Summary.

The overthrust junction of these rocks with the Carboniferous rocks was described in the Summary of Progress, 1908 (p. 39). Mr. Jones now finds evidence of another small lenticle of Carboniferous Limestone to the east of the exposure in Goultrop Road. This was worked many years ago about half-way up the steep cliff-slope due north of Talbenny church. No Carboniferous rock is visible *in situ* at present, but numbers of large blocks of a light-coloured intensely-sheared and veined limestone lie near the spot where the rock was quarried, while sheared diorite outcrops immediately above the old excavation. It is interesting to observe that both these lenticles are represented on the section of the coast given by De la Beche in 1829.

The order of intrusion of the various rock-types which make up the plutonic complex is clearly displayed in numerous sections. The fundamental type is a medium-grained dioritic rock containing variable amounts of quartz. This is accompanied by a rather basic modification, and also fades insensibly into more acid varieties which are of sensibly coarser structure and also contain more quartz, with considerably less hornblende than the main mass. Into this mass three distinct types have been intruded in succession and in the following order :—

Firstly, a fairly acid rock showing affinities to hornblende-granites or hornblende-syenites, but in which hornblende occurs only in subsidiary amounts, or may be altogether absent. This type does not differ materially from the acid modifications of the main mass, yet it may be observed in several places to cut clearly across some parts of that mass. It appears therefore that the same rock-type may have intrusive relations to another type at one place, and to grade insensibly into it at another place.

Secondly, *Pegmatite veins*. Certain parts of the coast show large numbers of acid veins consisting almost wholly of quartz and felspar which traverse the acid intrusions in all directions and cut abruptly across all the more basic types. The veins vary from mere threads and films to well-defined dykes several feet in width. *Lit-par*

intrusion of pegmatite into more basic rocks may frequently be observed. The quartz- and felspar-crystals attain a considerable size in some of the coarser varieties, but no clear examples of graphic intergrowth have been observed. In one case a vein about an inch in width had a string of white mica along the centre.

Thirdly and lastly, *Basic dykes.* In certain parts of the coast numbers of dykes of a dark fine-grained rock may be seen cutting all the modifications of the dioritic rocks as well as the pegmatite veins. They are therefore clearly the latest phase of intrusion, as might be inferred also from the fact that their edges are in every case distinctly chilled and the texture of the rock becomes gradually coarser towards the centre of the dyke. These vary in different cases from about 6 inches to 9 or 10 feet in width. In a small island near the west coast two distinct sets of these basic dykes are shown, one of which is of slightly later date than the other, though both have chilled edges, and there is no apparent difference in structure or composition between them. One set ranges in an east-north-easterly direction and the other in a north-westerly direction, and it is believed that the majority of the dykes inland may be grouped into two sets having approximately these directions.

The sequence of intrusion is therefore comparable with that observed by Dr. Flett among the "granulitic series" and later dykes of the Lizard complex (Summary of Progress for 1906, p. 30).

Some of the acid modifications of the fundamental mass, and especially the intrusions of the same type, have a well-defined gneissic structure which ranges in a general north-westerly direction, though this is not quite uniform over the whole area. This structure is only exceptionally observed in more basic types and may therefore have been set up during intrusion. This is suggested also by the presence of bands of a finer-grained rock of granulitic aspect, arranged in directions parallel to the foliation and grading insensibly into coarser types. Microscopic examination is required before the origin of these granulite-like bands can be referred definitely to movement during injection, though this is strongly suggested by the field-evidence.

The whole complex has suffered severely from the effects of post-Carboniferous movements which have set up numerous shear-planes dipping in a southerly direction at angles of about 30°. Along these planes the rocks have been smashed and brecciated, and certain bands have been converted into hornblende-schists. These structures are, however, much coarser and less uniform than the parallel structure described above. Moreover, the strike of the post-Carboniferous structures makes a large angle with the strike of the gneissic structure, as may be observed very clearly near the Life-boat Station in Goultrop Road, where the two kinds of structure are developed within a short distance of one another.

In the cove to the north of Mill Haven on the west coast the Old Red Sandstone is thrust over the plutonic series and a large area of the thrust-plane is laid bare. Small patches of a compact white flinty rock adhere to the plane, and tend to be arranged in lines in the direction of movement. These are believed to be portions of the plutonic series thoroughly crushed or mylonized by the movement of the superincumbent mass.

## ORDOVICIAN.

*Igneous Rocks.*—The volcanic series of St. Ishmaels, represented as intrusive greenstone on the Old Series geological map, extends westward past Marloes to Wooltack Point, beyond which it is continued through Midland Island into the island of Skomer. During the past season Mr. Cantrill has ascertained that the St. Ishmaels rocks are members of the more extensive Skomer series, a succession of extrusive igneous rocks with which are interbedded some quartzites, grits, and mudstones. From these sediments no fossils except a few indefinite traces of horny brachiopods, possibly *Lingulæ*, have been obtained.

The relations of the volcanic series to the surrounding Ordovician and Silurian formations can be examined only on the mainland. The igneous rocks everywhere appear to overlie Llandilo Flags, from which they dip away without obvious discordance. This appearance of normal superposition Mr. Cantrill regards as being probably deceptive; in one place the junction is vertical, and is certainly faulted. It is thus not unlikely that the igneous rocks are an older series thrust over the Llandilo Flags. The volcanic series is succeeded at Wooltack by Silurian conglomerates and mudstones, and is partly overstepped by them. Further, while in one section the base of the sediments can be shown to be of Upper Llandovery age, elsewhere strata of Wenlock age rest directly upon the volcanic rocks. That the Skomer series antedates the Upper Llandovery is clear, but in the absence of fossils we can merely suggest its comparison with the Arenig volcanic series of Llangynog and Trefgarn.

The easterly continuation of the Skomer volcanic series has been mapped by Mr. Thomas in the deer-park at Wooltack and Marloes. The Skomer series consists essentially of rhyolites and rocks that may be tentatively classed as andesites and basalts, interbedded with a thick series of sediments consisting of quartzites, sandstones, and red clays. On the mainland most of these types are represented, and all but the rhyolites are well displayed in the magnificent coast-section bordering on Jack's Sound, and along the north cliff of the Wooltack Peninsula.

The igneous rocks of the mainland are divided into two by a fairly thick series of quartzites and sandstones which runs more or less parallel to the north cliff and is not far removed from its edge. Quartzites form the shore-ends of most of the small bays which are themselves determined and bounded laterally by faults. On Jack's Sound the quartzites may be seen to advantage in Mouse's Haven.

Mr. Thomas also visited the Smalls Rocks, situated 28½ miles due west of Wooltack. They were found to consist of basalts similar in many respects to those present on the islands of Grassholm and Skomer. The islands of Ynys-bery, Ynys-Cantwr and others to the south of Ramsey Island were visited. They consist of columnar quartz-porphyries seemingly intruded into bedded rhyolitic tuffs. These tuffs, however, were only seen at the extreme south end of Ramsey Island. Without a more detailed study of the geology of the island, it would be impossible to determine the age of the quartz-porphyries.

These quartz-porphyries have furnished many of the boulders which occur in numbers on the coast to the south-east.

*Llandilo.*—An outcrop of Llandilo Flags has been mapped by Mr. Cantrill westward from Dale past Marloes, to the coast at Musclewick Bay, where the rocks are well displayed in the cliffs. They are sandy calcareous black flags roughly cleaved, and have yielded some of the usual Llandilo trilobites.

*Bala.*—A strip of Dicranograptus Shales (the "black slates" of the Old Series geological map) has been faulted up through the Carboniferous rocks of Druidston Haven, on St. Bride's Bay. The beds are black shales with graptolites, and are identified by Mr. Cantrill as belonging to the Mesograptus stage of the Mydrim Shales.

## Silurian.

In the cliffs of Marloes Bay, a thick series of shales, sandstones and conglomerates emerges conformably from below the Lower Old Red Sandstone of Dale, and rests unconformably upon the Skomer volcanic rocks. The series is found by Mr. Cantrill to include the Ludlow, Wenlock and Upper Llandovery stages, but the exact delimitation of each awaits the determination of the fossils. Low down in the series, probably in the Upper Llandovery, occurs a thin bed of contemporaneous 'basalt' which has hitherto been included with the Skomer series as an intrusive rock.

The grand section of Silurian rocks between Gateholm and Wooltack has been examined by Mr. Thomas. The lowest beds are exposed on the north side of Renney Slip and in the bay to the north; they consist of conglomeratic quartzites, with the sheet of 'basalt' previously noted, and of shales and rottenstones containing abundant Upper Llandovery forms. A few hundred yards northwards the dolerite reappears in the cliff but with a reduced thickness of sediments intervening between it and the Skomer volcanic series, as though there is some overlapping in the Silurian basal rocks.

Above the quartzites mentioned there follow sandy shales, with Upper Llandovery fossils, and calcareous mudstones. The latter, well exposed in Deadman's Bay, contain a fauna indicative of Woolhope and Wenlock horizons, and are comparable with some of the Tortworth strata. They are succeeded by a thick sandy series, poor in fossils, which gives place conformably to the Old Red Sandstone of Gateholm.

At Freshwater East Mr. Pringle has recognised representatives of both the Ludlow and Wenlock groups, corresponding in character to those rocks as developed on the north side of Milford Haven. But the absence of some strata which are developed in Lindsway Bay leads him to think that there is a slight gap between the two formations, as indeed is suggested by the conglomeratic character of the Ludlow basal bed.

## Old Red Sandstone.

An examination of Skokholm Island by Mr. Cantrill has shown it to consist of the red marls of the Lower Old Red Sandstone. The cleavage which affects the rocks along the southern edge of

the island has conferred upon them a superior durability which has resulted in the development of tors and ridges quite unlike anything found on the mainland.

On the south side of Milford Haven the red marls of the Lower Old Red Sandstone have yielded to Mr. Dixon *Cephalaspis* and eurypterids, while in the quartzites and breccias which had provisionally been assigned to the Upper Old Red Sandstone he has now obtained near their base, in Freshwater West, *Holoptychius*, a characteristic Upper Old Red fish. No evidence of discordance between the two divisions has been detected, but the upper division shows a marked tendency to thicken southwards, which is not shared by the lower, but which is observable in the succeeding Carboniferous strata.

## Carboniferous.

*Millstone Grit.*—In following the Basal Grit, which runs westward through Haverfordwest, Mr. Cantrill finds that it is overlapped near Nolton by the Middle or Shale subdivision. This latter is well displayed in the cliffs south of Druidston Haven (on St. Bride's Bay), where the shales are overlain by the Farewell Rock, a coarse yellow and white quartzitic grit. Much of the ground therefore which appears on the Old Series map as Coal Measures proves to belong to the Millstone Grit, the Coal Measures setting in farther south, at Haroldston West, and continuing in a southerly direction.

*Coal Measures.*—Mr. Thomas, in completing the mapping of the Carboniferous tract between Newgale and Nolton Haven, finds that the lowest Coal Measures occur on the northern side of Newgale Marsh and are followed by a shale-series with the most important coals. These have been worked along the southern side of the marsh and in the West Hills, and probably at Simpson also. The highest measures strike parallel to the coast to the north of Nolton and contain several good veins which have been worked on the cliff, and at the Folly and Trevrane. They are associated with strong sandstones, and thus form a series differing markedly from the shale-series below.

At Nolton also Mr. Cantrill finds the lower or shaly group with several coal-veins, most of which have been worked in past times, to be succeeded by the same upper or pennant-like sandstone-group, in which coals, though present, are less numerous. This group presents a general lithological resemblance to the Llynfi Rock and Pennant of other parts of the coalfield, a resemblance noted in 1846 by De la Beche.*

At Haroldston West, farther south, the basement beds of the Coal Measures come in with a south-westerly dip. About 20 feet above the base two fossiliferous horizons have been detected in the cliffs. The lower one is a marine band which has yielded several forms, including *Productus sp.*, *Orthotetes sp. nov.*, *Posidoniella laevis* (Brown), *Protoschizodus sp.*, and *Bellerophon sp.*

The upper horizon, 2 feet 6 inches above the other, is a goniatite-band; from it have been obtained *Posidoniella laevis* (Brown), *Pterinopecten papyraceus* (J. de C. Sow.), *Gastrioceras carbonarium?* (von Buch), and *Glyphioceras reticulatum* (Phill.).

* *Mem. Geol. Survey*, vol. i., 1846, p. 159.

## Structure.

A somewhat complex structure of the Coal Measures between Newgale and Nolton is noted by Mr. Thomas. From Nolton northwards the veins strike due north, with a westerly dip, but south of Chapel they turn abruptly eastward towards Trevrane, where they appear to be cut off by a north-and-south disturbance. They appear again to the north of Trevrane with a northerly strike, and after a short course turn westward along the low ground towards Bathesland and the sea.

The structure of the measures north of Nolton thus appears to be sigmoidal, the flexures being sharp and sometimes broken, while the axes of the folds have a rapid pitch.

At Nolton Mr. Cantrill finds several important structural features affecting the Carboniferous tract. In the first place the strong south-south-easterly dip which the Ordovician and Silurian rocks had acquired in pre-Carboniferous time has made the unconformity at the base of the Carboniferous rocks most conspicuous. One after another the outcrops of the older rocks in the old platform are overstepped by the Millstone Grit. But the platform having a slight declination southward, overlap within the Carboniferous series itself was set up. Thus at Nolton Cross the Basal Grit is overlapped by the shale-subdivision, which then rests directly on the Ordovician, and farther north, probably on the Cambrian rocks also.

The strip of Bala rocks heaved up through the Carboniferous formations at Druidston Haven is bordered on the south by Millstone Grit and on the north by high Coal Measures, the general effect of the faulting being therefore a large northerly downthrow.

Near Marloes the ground is much cut up by faults. An important line of fracture, having a north-west and south-east range, separates the Ordovician and Silurian tract of St. Ishmaels and Marloes from the Old Red district to the north. Other parallel fractures traverse the same region. Some other faults have a north-and-south range, but their relation to the north-west system is not clear.

In the area to the south of Milford Haven, Mr. Dixon notes that there is a number of faults ranging a little east or west of north, transversely to the dominant structures. He finds reason to believe that all may have been due to the same set of earth-movements. Motion along the transverse fractures was often horizontal or nearly so, and the relative positions taken up by the successive wedges, into which the district is split up by faults, is such as would result from compression in a north-and-south direction. There is, moreover, some connection, as regards direction, between the cleavage which is associated with the dominant structures, and the transverse faults. A change in the direction of cleavage accompanies a change in the direction of the faults, the two tending to keep at right angles to one another. In one case a transverse fault is proved to be of pre-Triassic age, by the fact that Triassic breccia has filled it. Some, however, of the cross-faults are certainly post-Triassic, for they cut through breccias of Triassic age.

### Raised Beach.

A Raised Beach has been observed by Mr. Dixon at Freshwater West at about the same height above sea-level as those in Gower and in Milford Haven. Though overlain by "head," there is no definitely recognisable Glacial Drift above it, but there is no reason to doubt that it also preceded the local glaciation. It is noteworthy for the number of igneous pebbles, especially quartz-felsites, which it contains. These must have had their origin in outcrops to the north of Milford Haven.

### Glacial.

South of Nolton Haven, Mr. Cantrill finds that brown and grey boulder-clay attains a thickness of 20 feet in places on the cliffs. In Druidston Haven, where it partly chokes a pre-Glacial valley, it forms a cliff 50 or 60 feet high. It contains boulders, some of local, others of more northerly derivation, with occasional flints; and, what is new to this part of Pembrokeshire, numerous fragments of marine shells, including *Astarte* (*Nicania*) *compressa?* (Mont.), *A. sulcata* (da Costa), *Mytilus edulis* Linn., *Pectunculus glycimeris* (Linn.), *? Tellina* (*Macoma*) *balthica* Linn., *Trophon* (*Boreotrophon*) *clathratus* (Linn.), *Trophon* (*Boreotrophon*) *scalariformis* (Gould), and *Turritella* sp. The Trophons are Arctic forms.

South of Druidston Haven, large isolated boulders of quartz-porphyry and diabase, &c. are so numerous that De la Beche, who noticed them in 1826, supposed that they were derived from an outcrop of "trap" in the immediate vicinity. No igneous outcrop however, occurs in the locality indicated, and the boulders can be referred to the craggy headlands of Ramsey Island and St. David's.

The cliffs at the northern end of Marloes Bay are capped with gravel of chiefly local origin. Isolated boulders of igneous rocks in the same district have been derived from the St. David's country.

A small patch of stiff "till" in West Angle Bay, to which our attention was called by Mr. A. L. Leach, has yielded to Mr. Dixon many fragments of marine shells. The deposit lies but a short distance above sea-level, and is overlain by what appear to be marine deposits. No shell-bearing drift has been found further inland.

## (B) SCOTLAND.

The ground surveyed in the Highlands was arranged in two districts as follows:—

1. West Highland District including Mull and South Morvern, under Mr. Clough, M.A.

2. North and Central Highland District containing parts of the counties of Sutherland, Perth, Inverness and Argyll, under Mr. Hinxman, B.A.

In the West Highland District, further progress was made with the mapping of Mull, in the south-west promontory (Sheet 43), in the tract adjoining Craignure and Loch Spelve, and in the Salen District (Sheet 44). In the North Highlands, field-work was continued in East Sutherland in Sheets 102 and 109, and in the Central Highlands in Sheet 54.

The Coalfield areas were grouped in two districts:—

3. Shotts and Fauldhouse District, under Mr. Clough, M.A.

where further progress was made with the revision of the Coal Measures in the neighbourhood of Caldercruix and near Shotts.

4. Kilbride and Carluke District, under Mr. Hinxman, B.A. The small area in the Carron and Slamannan District left unfinished at the end of 1908, composed partly of Coal Measures and Millstone Grit, was completed and the revision of the Carboniferous areas around East Kilbride, Carluke and Douglas was begun.

### 1. West Highland District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A.
Mr. H. B. Maufe, B.A.
Mr. E. B. Bailey, B.A.
Mr. T. O. Bosworth, B.A., B.Sc. } Geologists.

The areas surveyed lie in the one-inch maps 43 and 44, and are situated in the Island of Mull and the adjoining district of South Morvern.

#### *Ross of Mull.*

NEWER GRANITE AND ACCOMPANYING METAMORPHISM.

Mr. Bosworth reports that the mapping of the granite is now completed. It extends over some 20 square miles and varies remarkably little in composition and texture except along the line of junction with the schists where there is considerably more mica than in the interior, probably owing to absorption of mica schist. Inclusions are very abundant near this boundary, but they are also quite plentiful throughout the area, and in the central part a number have been mapped, some of them two or three hundred yards in length.

Most of these large inclusions, like the schist at the margin of the granite mass,* have been very highly metamorphosed and now contain a large amount of sillimanite, andalusite and cordierite, the first-mentioned mineral enclosing numerous minute grains of green spinel. This association of minerals is the same as that noticed in the schists altered by the Ben Cruachan "Newer Granite" intrusion,† and also at the margin of the Newer Granite at Netherly in Elgin.‡

The sillimanite in these Ross of Mull rocks is particularly interesting, as it occurs in larger crystals than have hitherto been found in Scotland. They are in long prisms apparently of the form (230), often about $\frac{1}{100}$ inch in thickness, and give "diamond shaped" cross sections crossed by the traces of a strong pinakoidal cleavage. These cross sections show a very low grey colour between crossed nicols and give good interference figures.

Some small masses of diorite were met with in the west of the Ross of Mull on the shores of Erraid Sound. This rock was formed earlier than the granite§ which has cut it and penetrated into it to

* "Summary of Progress" for 1908 (*Mem. Geol. Surv.*), 1909, p. 56.

† J. J. H. Teall. "Summary of Progress" for 1898 (*Mem. Geol. Surv.*), 1899, p. 86, &c., also "The Geology of the Country near Oban and Dalmally" (*Mem. Geol. Surv.*), 1908, p. 143.

‡ J. S. Flett. "The Geology of Lower Strathspey" (*Mem. Geol. Surv.*), 1902, p. 52.

§ E. H. Cunningham Craig. "Summary of Progress" for 1907 (*Mem. Geol. Surv.*), 1898, p. 66.

such an extent that it is sometimes difficult to decide whether to map the rock as granite or as diorite. Owing to the uniform character of the granite there is little evidence of faulting within it, but in the section along the north coast several small faults are proved by the shifting of the intrusive sheets of mica trap which are there exposed. These faults have a northerly trend, the largest throw observed being about 25 feet down to the east.

### MINOR INTRUSIONS.

On examination of the coast sections Mr. Bosworth finds that minor intrusions cutting the Ross of Mull granite are numerous, though inland they are generally concealed, as they weather away more readily than the granite. There appear to be at least three sets of minor intrusions later than the regional metamorphism of the Moine Schists. The oldest of these is pre-granite, and is represented by one inclined, slightly foliated, micaceous sheet, some 2 ft. 6 in. thick, seen on the coast a quarter of a mile south of Rudha na Traighe-maoraich cutting the psammitic Moine rocks near the eastern margin of the granite. Tongues and offshoots from the granite mass pierce the Moine rocks near this sheet, and clearly send small veins and strings of granitic matter into it.

Next, cutting the granite are numerous sheets, sometimes 9 or 10 feet thick, of mica trap (well seen on the north coast) and granite porphyry (well seen on the west coast). The mica trap often contains many small inclusions of granite, granulites and quartz. Some of these sheets have been disturbed by small faults, as already mentioned. Lastly, there is a set of north-west dykes which cut the sheets of mica trap, and are later than the faults above mentioned. This is well seen in the coast section on the west side of Port Gart an Fhithrich, where one of the north-west dykes in the granite is seen crossing a sheet of mica trap and departing from its normal course for a few yards along the plane of a fault which has displaced this sheet.

Some of these dykes seem to have produced changes in the granite at their margins. The dyke rocks vary somewhat in appearance, though generally they are heavy, dark and fine in grain. One specimen (14267), from the coast nearly 800 yards south-east by south of Beinn Liathanach, has been examined under the microscope by Dr. Flett, and is classed with the camptonites.

### *The South-East Part of Mull.*

In the Summary of Progress for 1907 Mr. Bailey gave a section (Fig. 2, p. 68) illustrating the intense folding characteristic of the eastern corner of Mull. The folds in this district like some mapped by Mr. Wedd in Skye, have remarkable curved axes; in fact the rounded outline of the Mull coast is in large measure indirectly determined by the trend of these folds; at Port Donain (Fig. 1) they are crossed by an interesting wrench or tear-fault which displaces them laterally for a distance of about 200 yards. Schists, Old Red lavas, Mesozoic sediments and Tertiary lavas are all involved in these disturbances. Of the two former there is nothing new to report, but the Mesozoic rocks have been investigated by Dr. Lee, who furnishes the following account.

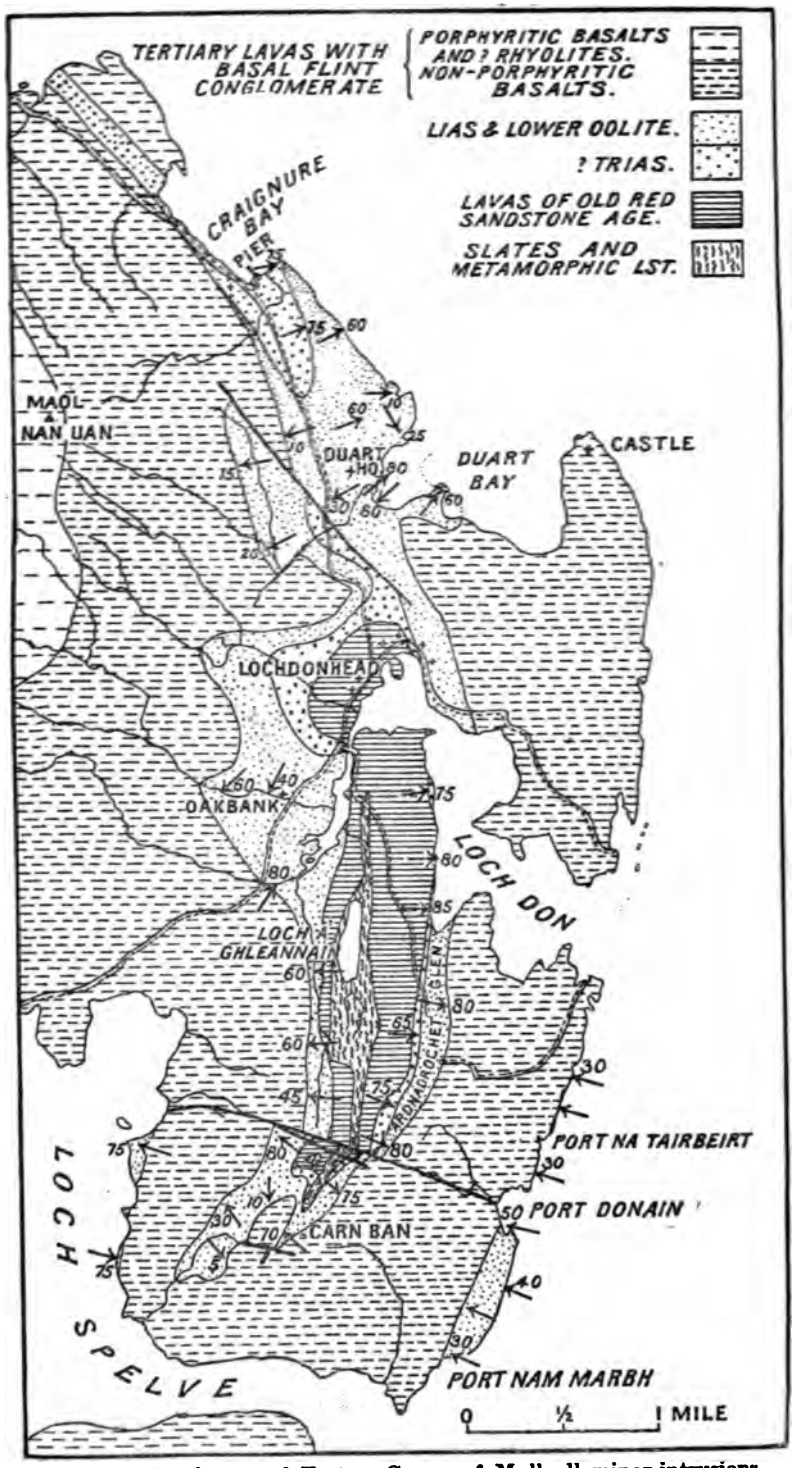


Fig. 1. Sketch map of Eastern Corner of Mull, all minor intrusions omitted.

### TRIAS.

The lowest member is an unfossiliferous quartz conglomerate referred by Prof. Judd* to the Trias.

### LIAS.

Next in conformable sequence follow about 20 feet of a hard compact limestone generally of a dark hue, but, curiously enough, white on the shore immediately south-east of Craignure. The only fossils observed—a *Lima*-like lamellibranch and an ostreiform shell—are too badly preserved to be of any zonal value.

This limestone passes up into a shelly limestone, a few feet thick on the shore between Duart and Craignure, and nearly 40 feet in the Ardnadrochet Glen. It contains bands crowded with *Gryphaea arcuata* Lam., but no ammonites were found in this district. However, Prof. Judd has shown that, not very far off, on the shores of Loch Aline, Morvern, this fossil is accompanied by ammonites characteristic of the Bucklandi Zone. On the Craignure-Duart shore and in the Ardnadrochet Glen the *Gryphaea*-limestone is followed by rusty coloured shaly micaceous sandstone, with poorly preserved ammonites in the former locality. It is probably in these beds that Prof. Judd detected near Duart ammonites characteristic of the Semicostatus Zone.

The upper portion of the Lower Lias is represented by a considerable thickness of calcareous sandstone—typically developed on the coast between Port Donain and Port nam Marbh, and in the Oakbank Burn. With the exception of abundant specimens of *Pecten equivalvis* J. Sow. and *Gryphaea cymbium* Lam. no characteristic fossils were observed, but on the coast of the peninsula stretching south of Loch Spelve the same series of strata has yielded two ammonites, which, though poorly preserved, seem to point to the presence of the Armatus and Capricornus Zones.

At Port nam Marbh the top beds of calcareous sandstone just referred to are characterised by *Gryphaea* cf. *gigantea* J. Sow., and have yielded an obscurely preserved *margaritatus*-like ammonite; these beds and a thick superincumbent white sandstone—a good freestone—may therefore be placed in the Middle Lias, a classification in agreement with Prof. Judd's observations in the Carsaig district.

The Upper Lias is so generally denuded away in Mull that it escaped detection until last summer. In the Loch Don district it is represented, on the coast from Port nam Marbh to Port Donain, by 30 feet of indurated dark shale overlying the white sandstone referred to above, and underlying limestones of Lower Oolite age. At Port Donain this shale yielded an ammonite closely allied to, if not identical with, *Dactylioceras commune* (J. Sow.). A small patch of similar shale occupies the same position at Port na Muice Duibhe, two and a quarter miles south of the mouth of Loch Spelve, where it contains *Dactylioceras sp.* and *Harpoceras* cf. *mulgravium* (Y. and B.).

* "The Secondary Rocks of Scotland. Third Paper. The Strata of the Western Coast and Islands." (*Quart. Journ. Geol. Soc.*, vol. xxxiv., 1878, p. 660).

### LOWER OOLITE.

Equally interesting is the discovery of Lower Oolites in the Loch Don district. At Port Donain and Port nam Marbh about 70 feet of calciferous sandstones and sandy limestone, containing in their lower beds ammonites indicative of the Concavi and Discitae Hemerae, rest on the eroded surface of the Upper Lias shale. In the Ardnadrochet Glen the Lower Oolites are in contact with the Middle Lias sandstone, and are represented by two beds of limestone separated by some 30 feet of decalcified calciferous sandstone with casts of lamellibranchs. The lower limestone bed appears to have been deposited before the lowest bed yielding Oolitic fossils in the coast section, since it contains an assemblage of fossils characteristic of the Scissi Hemera. The top bed contains an ammonite indicating the Concavi Hemera, but owing, perhaps, to the nature of the rock, which makes collecting difficult, the two intervening zones—*i.e.*, of *Brasilia bradfordensis* and *Ludwigia murchisonae*—are not yet located. Beds, presumably of the same age, occur on the west side of the Loch a' Ghleannain anticline. A small outcrop of limestone on the shore of the bay a quarter of a mile south-east of Duart House, may tentatively be placed in the Lower Oolites, but the ammonite on which this correlation is based, is very poorly preserved.

These are the only Lower Oolite beds as yet known in Mull. In the Carsaig section the Greensand rests directly on the Middle Lias, and a small patch of Upper Lias is the highest member of the Mesozoic sequence observed in the long coast section stretching from Loch Buie to Loch Spelve.

### UPPER GREENSAND.

Prof. Judd has made known the presence of Upper Greensand at Gribun and Carsaig in Mull, and at Loch Aline in Morvern: a glauconitic sandstone lithologically very similar to that of Carsaig and Loch Aline, and crowded with a crushed ostreiform shell, occurs at Port Donain and north of Port na Tairbeirt. In places, it passes upwards into a *remanié* conglomerate, where fragments of the ostreiform shell are mingled with pebbles of flint and silicified chalk.

### TERTIARY.

Mr. Bailey finds that the Tertiary lavas of eastern Mull are divisible into

(*b.*) Porphyritic Basalts and ? Rhyolites.

(*a.*) Non-porphyritic Basalts.

Further towards the centre of the island, which appears to have a general basin structure, the upper lavas (*b*) are covered by a thick breccia charged with lava, schist, granophyre, gabbro and sandstone fragments, all heaped together without assortment. In Sgurr Dearg, north-west of Loch Spelve, this breccia can be followed on to a mountain of schist rising up through the lavas, and is here particularly crowded with schist debris; it also locally rests upon the highly eroded surface of a gabbro which is intrusive in the schist. No lavas have been found connected with the breccia, and

its formation may well mark a respite in the volcanic history of Mull, perhaps contemporaneous with the break already recognised in the Ulster sequence. The conditions leading to the production of such a thick unbedded breccia require a much fuller investigation, however, than has yet been possible.

As Prof. Judd* and Sir Archibald Geikie† have shown, the central portion of Mull is everywhere flooded with intrusive igneous rock. In the east these intrusions consist mainly of dolerite, ranging to gabbro, and are disposed in innumerable sheets inclined towards a central axis, in the manner described by Mr. Harker for the later portions of the Cuillin complex in Skye.

The regularity of the inclined sheet complex in the present instance is very remarkable, especially as the component sheets traverse not only the lavas but also the overlying unbedded breccia and, most striking of all, the mountain of schist rising in the midst of these accumulations. In fact so close are the intrusions that the schist massif, with its vertical bedding, has to be pieced together from thin slices which intervene between successive sheets of the intrusion complex. Often, too, the sheets are in actual contact or one sheet cuts another. In every case in this district it appears that individual sheets are chilled at top and bottom.

Some stray members of this great intrusion complex continue east of Loch Spelve, and cross at right angles part of the folds shown in the sketch map (Fig. 1). The intrusive sheets here are quite unbroken although they traverse lavas which have been much shattered by the severity of the folding movements. Clearly then the folding is not wholly later than the period during which the inclined sheets were intruded, for, if it had been, none of the sheets could have escaped; it may, however, have been contemporaneous, for the intrusion was obviously intermittent, and *ex hypothesi* the later members of the complex would escape the main disturbances. The complex is in the aggregate of great thickness, so that, to make room for it, the country rock, must necessarily have suffered important displacement; the peripheral folding may then be part of the expression of this displacement, and it may be for this reason that the curved axes of the folds are concentric with the curved outline of the complex.

### *Salen District of Mull.*

#### TERTIARY.

The country mapped by Mr. Wright in the Salen district, on the north side of the plutonic mountain mass of Mull, is built up largely of lavas and granophyre (*see* Fig. 2). The margin of the latter is for the most part nearly vertical and abruptly cuts off the horizontally bedded lavas. In the hills to the south of Salen village there are, however, a number of more or less irregular dyke-like and sheet-like offshoots.

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* "The Secondary Rocks of Scotland, Second Paper. On the Ancient Volcanoes of the Highlands and the relations of their products to the Mesozoic Strata." *Quart. Journ. Geol. Soc.*, vol. xxx., 1874, p. 220.

† "Ancient Volcanoes of Great Britain," vol. ii., 1897, chaps xliv. and xlvii.

The principal result has been the establishment of the existence of a curving fault parallel to the vertical margin of the granophyre and about a mile within it. This fault displaces the roof of the granophyre by an amount estimated at something between 500 and 1,000 feet, and has its downthrow towards the interior. The lavas which form the summits of the hills on both sides of the upper reaches of Loch Ba and Glen Cannel are the indurated roof of a great granophyre mass which is exposed in the bottom of the glens. Outside the fault this roof lies much higher and is only found as a capping on the summits of the loftier hills, such as Beinn a' Ghràig

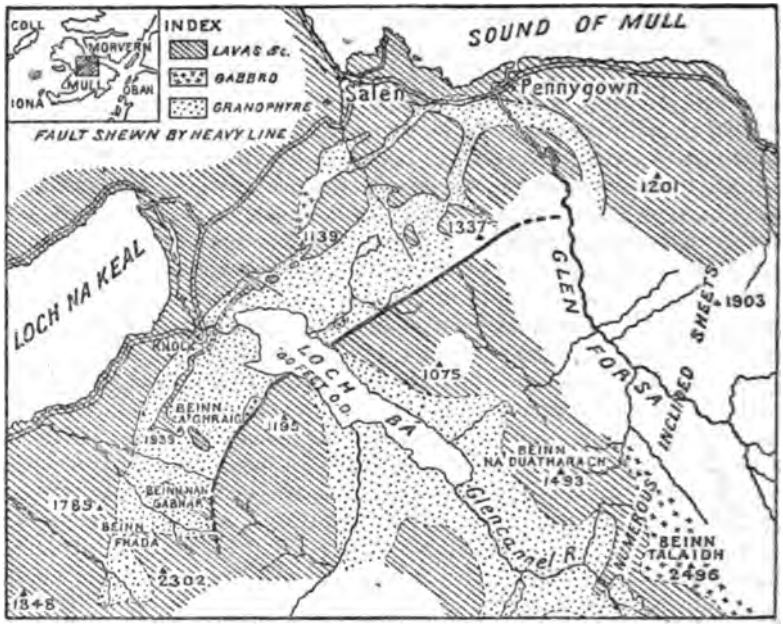


Fig. 2. Sketch map of the Granophyre on the north side of the Plutonic Complex of Mull. All minor intrusions omitted, doubtful or approximate boundaries shewn as broken lines. Scale 2 miles to an inch.

and Beinn nan Gabhar. At a number of places along the fault the granite is seen to be highly brecciated. and the adjoining lavas on the inner side of the fault dip at steep angles. The age of this displacement is to some extent defined by the fact that it is traversed by many of the north-west basic dykes, which there is reason to believe are the latest manifestation of igneous activity in the district. Since the faulting affects the granophyre and not these dykes, it is clear that it must be referred to the earlier part of the epoch of minor intrusions which succeeded the introduction of the plutonic rocks. The principal event of this period, so far as the plutonic centre is concerned, was the introduction of the basic inclined sheets, which bulk so largely in other parts of the island. These sheets are, to say the least, extremely rare in the granophyre district of the north, and it is suggested that the central subsidence, which is recognised as a phenomenon frequently associated with

volcanic centres,* may have been eased in the south and east of the island by the introduction of the inclined sheets along cracks in the subsiding mass, while in the north-west it found no such compensation and so became apparent as a circular fault. The evidence in support of this suggestion is the double coincidence (1) of the occurrence of the fault in that part of the periphery of the plutonic centre in which the inclined sheets are absent, and (2) its production at the stage in the history of the centre at which the inclined sheets were introduced.

An interesting observation was made near Knock on the north-west margin of the granophyre mass. This margin is almost vertical, the nearly horizontal lavas being abruptly truncated in the manner figured by Sir Archibald Geikie in his "Ancient Volcanoes of Great Britain" (vol. II., p. 396). About a quarter of a mile further inland, in the midst of the granophyre, a vertical screen of lava occurs, which can be traced over hill and valley from sea level up to the 1750-foot contour. This screen varies much in thickness, being as little as 10 feet in one place, but reaching 300 feet in others. It is, however, apparently continuous as far as it has been traced, and maintains a remarkable parallelism with the outer wall of the granophyre. On Beinn a' Ghraig it joins up with the remnant of the roof of the granophyre which is preserved on the summit of that hill.

The explanation that most readily suggests itself is that the granophyre on the outside of this screen is a distinct intrusion from that inside, and that the screen owes its preservation to its having been indurated by the contact metamorphism of the earlier of the two intrusions, and so enabled to resist destruction by the second. As they have not yet been observed in contact, direct evidence of the relations of these two plutonic masses is wanting, and they are so similar in appearance that it is doubtful if this will ever be obtained. The fact that the margin of the inner granophyre in contact with the screen is extremely resistant, and stands out frequently as prominent scars, might, however, be taken as an indication that it has been somewhat baked by the outer granophyre, which therefore would be the later.

Observations on the minor basic intrusions of the Salen district show, as far as they go, similar relations to those found in Skye. The *north-west "regional" dykes* predominate and for the most part cut all the other igneous rocks. Other systems of dykes are, however, more or less obvious, in particular a well marked *tangential set*, the parallelism of which to the circumference of the circular area occupied by the Mull plutonic rocks is very striking. The situation of the Salen district is not suited for the separation of radial dykes from those of the north-west set mentioned above, but along the shore of the Sound of Mull between Pennygown and Fishnish Bay there are numerous dykes running N. to N. 15 E., which are quite distinct from the north-west dykes, and are probably to be referred to a radial series.

* For a discussion of the central subsidence of Mull, *see* p. 256 of Prof. Judd's second paper, already referred to.

Intersections of dykes belonging to the different sets have not been very often observed. The most frequent cases are merely where the north-west dykes cut those of the tangential or supposed radial sets mentioned above, but at Leth Thorcaill, a mile and a half east of Fishnish Bay, a tangential dyke has been observed cutting one of the presumed radial dykes. This is supported by another instance on the shore west of Pennygown, but the dyke that is cut is not in this instance so obviously radial and might belong to the north-west set.

That the introduction of the plutonic rocks was preceded by a period of dyke intrusion quite comparable with that which followed it is shown by an exposure on the hillside south of the burial ground at Knock. Here a distinctly tangential dyke cuts and is chilled against a north-west dyke, and is in its turn cut and veined by the granophyre.

Of minor intrusions other than vertical dykes relatively few have been observed in the Salen and Gruline districts. A well marked inclined sheet follows the shore of the Sound at Faoileann Ghlas for a distance of half a mile; another is observable at Salen, and another on the roadside between Salen and Gruline; all dipping at low angles towards the plutonic centre and transgressing the bedding of the lavas. Outside the granophyre margin in the neighbourhood of Knock are numerous acid sheets which dip inwards towards the granophyre. Their connection with the latter has nowhere been directly observed.

During the latter part of the season Mr. Wright was engaged in mapping on Beinn Talaidh, a mountain in the central portion of the plutonic district of Mull. The geology here, as in the east of the island, is complicated by the extreme abundance of the minor basic intrusions. Of these by far the most numerous are the inclined sheets, which usually dip at angles of 50–60° towards a point lying a little to the west, on the southern slopes of Beinn na Duatharach. The convergence of the dip of the sheets towards this point is very marked, the strike swinging round from N.N.E. on the south-west slopes of Beinn Talaidh to N.N.W. on the north-west slopes. A relation similar to that found in Skye, where the inclined sheets of the Cuillins and Blaven all dip towards a common centre, is in this manner definitely indicated.

The south-western slopes of Beinn Talaidh are composed largely of acid or subacid lavas. These latter form an irregular belt running in a north-westerly direction and flanked on the south-west by the granophyre and on the north-east by the gabbro. The granophyre margin where exposed is vertical or steeply inclined, that of the gabbro is never clearly seen. Indeed so obscure is this margin that it is not at all clear whether the gabbro is massive at its edge or composed of a series of sheets. This is largely due to the great abundance of the inclined sheets on the upper slopes of Beinn Talaidh, and the difficulty of distinguishing, in poor exposures where chilled edges cannot be traced, between certain types of inclined sheets and some varieties of the lavas. The upper scree-covered slopes and the summit are largely composed of fine-grained rocks, which are either sheets or lavas, and the gabbro

is only seen in lenticles and bosses here and there. An examination of most of these masses showed that every fine-grained rock observed in contact with the gabbro is chilled against it. This supports the idea that the summit of the mountain is largely composed of inclined sheets. The presence of the belt of lavas between the gabbro and granite suggests the conclusion that the later of these intrusions has been unable to penetrate the zone of contact metamorphism of the earlier.

### *South Morvern.*

On the mainland in Morvern Mr. Maufe mapped a strip of country lying near the coast and west of Loch Aline. As was to be expected, it is occupied by the Tertiary basalts belonging to the Mull plateau-lavas, overlying a group of Mesozoic sedimentary rocks, which in turn rest unconformably upon gneisses. The whole series is traversed by dykes and a few intrusive sheets of those types commonly associated with the Tertiary igneous rocks, whilst one or two unfoliated dykes are intrusive into the gneiss only, and probably belong to the Lower Old Red Sandstone igneous suite.

### METAMORPHIC ROCKS.

The gneisses exposed at the head of Loch Aline are coarsely crystalline quartz-biotite and muscovite-biotite gneisses, the foliation of which strikes N.N.E. and S.S.W. They are very similar to the gneisses of the country further north, about Strontian and Ardgour, which were described in the *Summary of Progress* for 1901 (p. 120), and 1903 (p. 60), and like them belong to the Moine Series.

### MESOZOIC ROCKS.

The lowest group of the Mesozoic sedimentary series consists of coarse-grained sandstones and red marls, and has been referred to the Trias by Prof. Judd. Near Kinlochaline the basal member of the series, consisting of a breccia made up of sub-angular blocks of gneiss, may be seen resting unconformably upon muscovite-biotite gneiss. The breccia passes up into a pebbly grit, overlain by a poorly exposed series of red marls. The latter are capped in turn by a coarse white sandstone containing limestone nodules, which are pale grey or white in colour, and have the irregular knobby surface so characteristic of the cornstones from the Old Red Sandstone.

These cornstones are easily distinguishable from the calcareous nodules found in many marine strata, but Mr. Maufe states that they resemble very closely in their form and disposition within the bed the limestone concretions found in the superficial deposits of many tropical lands. They are widely known as "kankar" in India, where they afford very frequently the only source of lime over large areas, and the same may be said of many parts of Central Africa. Their mode of origin throws some light on the conditions obtaining in Morvern in early Mesozoic times. They

occur in districts subject to alternating dry and wet seasons, where the rocks containing lime-bearing silicates are undergoing atmospheric decay. At the end of the rainy season the subsoil is charged with water containing salts of the alkalies and alkaline earths in solution. As this water percolates into the stream-channels or is evaporated, calcium carbonate is deposited owing to loss of carbon dioxide, and perhaps also owing to reaction between the lime and alkali salts. The concretions are thus formed in the subsoil at some depth depending on the water-level, and they may by a continuation of the process become cemented together to form a lenticular bed. Though they may form in alluvial deposits, they are thoroughly characteristic of terrestrial conditions, and it is apt to be misleading to call them freshwater limestones.

The breccia and red marls mentioned above show that arid continental conditions prevailed in Morvern in pre-Liassic times. We see that the overlying white sandstone with its cornstones is also of terrestrial origin, and that the climate of the period was arid for at least a portion of the year.

The succeeding beds have a shallow-water marine facies, and belong to horizons in the Lower Lias and Upper Cretaceous, as Prof. Judd has pointed out. The most striking feature of these strata are the shell-beds, consisting of innumerable *Gryphaeae* in the Lias and *Exogyrae* in the Upper Cretaceous rocks.

### TERTIARY.

In the area examined by Mr. Maufe the Tertiary volcanic series rests on the Cretaceous rocks, and consists of a monotonous succession of basaltic flows. The majority of these flows are massive in the centre, each becoming amygdaloidal and brecciated or scoriaceous towards its top and base. The amygdaloidal band at the top is always thicker than that at the bottom, and is further marked by purple and red staining along the irregular line of junction with the brecciated and vesicular but unstained base of the overlying lava. The upper and lower bands weather more readily than the massive central parts, which therefore stand out to form terraces and lines of crag. The vertical joints in some of these solid cores are frequently arranged on the hexagonal pattern, but the columns are never so distinct as in the case of intrusive sills. In other cases a horizontal platy jointing parallel to the flow-banding is dominant.

A neck filled with red agglomerate pierces the lavas on the shore near Fiunary, about four miles west of Loch Aline. Acid rocks, whether intrusive or extrusive, are extremely rare. Up to the present the only ones noticed are a beautiful pitchstone dyke on the shore near Fiunary pier, and a mass of biotite-trachyte forming a line of conspicuous crags on the hills above Savary.

In addition to the basalt dykes having the normal north-westerly trend, there are many with a more northerly course. It is not yet clear whether or not the latter belong to the local set radial from the Mull centre.

A few thin inclined sheets having a columnar structure and chilled upper and lower margins were also mapped.

## *Salen District of Mull and Morvern.*

### PLEISTOCENE AND RECENT.

Reference was made in the *Summary of Progress* for the year 1908 (p. 57) to the manner in which the ice which moved W.N.W. along the Sound of Mull changed its direction suddenly in the neighbourhood of Salen, and crossed in a south-westerly direction over into Loch na Keal. Striae observed in the country to the north of Salen have now made it apparent that the cause of this deflection was the pressure of a powerful ice stream which came from the north-east, off Morvern. In the congestion caused by the junction of these two flows we have an explanation of the very exceptional ice-moulding of the Salen pass.

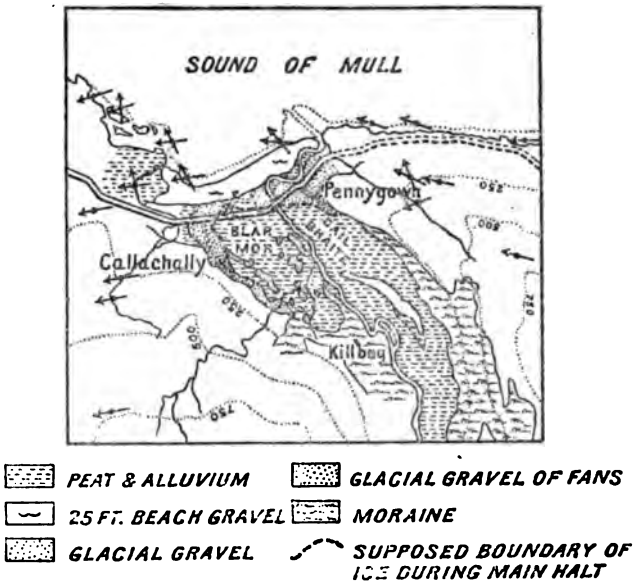


Fig. 3. Sketch map of the lower part of Glen Forsa, shewing the eskers, gravel fans and moraines of the local glaciation, as well as the striae of the general and local glaciations.

The drift deposits of Glen Forsa and the valley of Loch Ba have been found by Mr. Wright to present some unusual features. The glaciers which occupied these valleys have formed the usual type of morainic drift in the upper reaches, but near the mouths of the glens they deposited extensive masses of gravel. This gravel takes the form of terraces, fan-like sheets, and mounds, and there are several well-marked linear eskers. At Callachally in Glen Forsa (*see* Fig. 3) one of these eskers terminates in a clearly defined fan, which slopes away from the end of the esker in all directions, and drops with an unbroken surface to a level of about 35 feet O.D., where it passes beneath the gravels of the 25-foot beach. There is a small but distinct esker extending continuously for about a quarter of a mile along the side of the river half a mile east of Callachally, and at Pennygown there is a remnant of another outwash fan. It is noteworthy that the striae on the shore prove the Glenforsa

glacier to have extended right out into the Sound of Mull,* so that this gravel formation does not appear to have been deposited at this period of its greatest extension. It was on the contrary a product of a certain stage of the retreat, and its production was most likely accompanied by a halt or slight readvance of the ice-front. The position of the latter at this stage is almost certainly marked out by the steep fan of gravel bounding the peat moss of Blar Mor. This peat moss and that of Dail Bhaite on the east side of the river occupy a hollow which is in fact a cast of the form of the glacier at this stage.

The mounds which rise here and there above the peat for about a mile up the glen are all composed of gravel. At Killbeg, however, a sudden change sets in, and the gravel gives place to clayey moraine, forming the hummocky topography so characteristic of Highland glens. From here to the head of Glen Forsa there appears to be no further deposits of gravel.

Similar phenomena are observed in the valley of Loch Ba. During its maximum the glacier which occupied this valley appears to have extended into Loch na Keal, as is indicated by some cases of cross striae on the shore, similar to those of the Glen Forsa glacier. The first stage of retreat of which any record is visible is characterised by gravel formation, and the position of the ice front during the main halt is very obviously indicated by the present limits of Loch Ba.

The gravel belt is characterised by mounds, eskers and outwash fans similar to those of Glen Forsa, and gives place in the same manner to morainic drift a little further up the valley.

These two well marked cases would alone be almost sufficient evidence on which to base the general conclusion that during the retreat of the Mull glaciers there was a distinct phase which was accompanied by marked production of gravel. In the east of Mull, however, Mr. Bailey has found what appears to be another case in the occurrence north of Loch Don of great masses of glacial sand and gravel, probably produced by confluent glaciers from the hills to the west.

In South Morvern, Mr. Maufe found that the district surveyed is almost bare of glacial deposits, a stiff stony boulder-clay alone occurring in a few of the hollows. The direction of striae and of the carry of the boulders indicates an ice-flow in a south-westerly direction across the Morvern plateau, whilst along the shore of the Sound of Mull the direction was more westerly, and down Loch Aline more southerly. The latter direction is probably the effect of "undertow" during the passage of the main ice-sheet. In the absence of cross-striae and of that hummocky morainic drift which is so characteristic of the later valley glaciation, it seems probable that the valley glaciers did not reach down to sea-level in Loch Aline. The conditions, therefore, were different from those prevailing in Glen Forsa on the opposite shores of the Sound of Mull, described by Mr. Wright. This difference may perhaps be correlated with the lower elevation of the hills and the southern aspect of the *névé* in Morvern.

* "Summary of Progress" for 1908 (*Mem. Geol. Surv.*), 1909, p. 57.

## 2. North and Central Highland District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers.
Mr. M. Macgregor, M.A., B.Sc.
} Geologists.

The field work was carried on during the summer in East Sutherland by Dr. Crampton in the district of Forsinard and Kinbrace (Sheet 104), and by Mr. Macgregor at Lairg (Sheet 102).

In Perthshire and Inverness-shire the mapping of Sheet 54 was continued by Mr. Carruthers in the ground to the east of Loch Ericht, by Mr. Hinxman between that Loch and Glen Lyon, and by Mr. Anderson in the centre of the Moor of Rannoch.

### *Sutherland.*

#### HIGHLAND METAMORPHIC ROCKS AND ASSOCIATED IGNEOUS INTRUSIONS.

The Strath Halladale and Kinbrace granite-gneiss complex has been further studied by Dr. Crampton in the area around the two Beinn Griams. The granite presents two phases of intrusion, a granite which is frequently porphyritic, and a later aplite which occurs in the form of sills and dykes. The granite has saturated the schistose rocks, forming a series of complex synthetic gneisses.

These synthetic gneisses vary both according to the degree of saturation and metasomatism that has taken place, and also with the original character of the rocks into which the magma has been introduced. Certain well-marked types are in this way produced, the origin of which can at once be recognised. The foliated granites are all synthetic in origin, and there is no reason to believe that they have been subjected to movement.

A series of rocks, determined by Dr. Flett as amphibolites, pyroxene-amphibolites and pyroxene-gneisses, occur locally. These are earlier than the granite by which they are pierced and permeated. The original "country" rock consists chiefly of the pelitic and siliceous schists of the Moine Series, but other rocks are present which there is good reason to believe are of Lewisian age. These, like the others, have been penetrated by the granite magma.

The area mapped by Mr. Macgregor in the neighbourhood of Lairg is occupied by schists of the Moine Series and granite intrusions. The prevailing type of the former is a banded siliceous granulite in which quartz and biotite are the predominant constituents. Highly siliceous rocks, approaching quartzite in character, also occur, together with a few thin bands rich in flaky biotite. The schists dip with remarkable regularity in a direction slightly to the north of east.

The granite varies considerably in character, but two tolerably distinct types can be recognised, the one a rock of coarse texture with large orthoclase phenocrysts and scanty hornblende, the other less coarse and more of the nature of a quartz-diorite, with a good deal of green hornblende. The marginal relations of the schist and

granite present the usual complex, and, around the latter, a belt of the "country-rock" of varying width is impregnated with granitic material and affords good examples of *lit-par-lit* intrusion.

A small area of foliated granite has been met with half a mile south of the foot of Loch Shin. It shows a coarsely foliated, augen-gneiss structure, and is probably connected with the augen-gneiss intrusive masses on the south side of the Kyle of Sutherland.

Several well-marked crush lines traverse the area in a general N.W.-S.E. direction. One of these faults, which has defined the gorge of the Allt a' Ghleannain, forms the south-western boundary of the main granite mass.

### OLD RED SANDSTONE.

The Old Red Sandstone in the district of the Griams examined by Dr. Crampton, is found to have a wider distribution than was formerly supposed. It forms nearly the whole of Ben Griam More, the top and part of the flanks of Ben Griam Beg, and caps the summits of Meall a' Bhuirich and Beinn a' Mhadaidh. The last named exposure is an outlier from the main mass, but the three first-mentioned heights are connected by the deposits which fill the hollows of the ancient floor and extend as far westwards as the Rimsdale Burn. The unevenness of this earlier surface is further emphasised by a hill of crystalline rocks which rises in the heart of the sandstones of Griam More, but is bounded on the east by a post-Old Red Sandstone fault. A number of other north-and-south faults with downthrow to the east traverse the area, and are conspicuous by their faulting of the band of quartzite-conglomerate which forms part of the series. The general dip of the sedimentary rocks is to the west and the sequence is as follows :—

1. Basement conglomerate of rounded, sub-angular, and angular fragments of granite and schists of local origin.
2. Thick reddish arkose with thin conglomerate bands.
3. Conglomerate composed of sub-angular fragments of the Scaraben quartzite in an arkose matrix.
4. Red mudstones and arkose bands.

A point of interest is the small volcanic neck which pierces the sandstone on the east shoulder of Ben Griam More. It is oval in shape, measuring about 50 by 25 yards. A preliminary examination of the volcanic rocks in the plug by Dr. Flett shows them to be quartz-porphyries and olivine-free basalts. The sandstone surrounding the neck has been much altered and vitrified, and a curious spherulitic structure has been developed in some of the altered rocks.

### PLEISTOCENE AND RECENT.

Loch Leum a Chlamhain, a small loch north of Ben Griam More, is surrounded by a well-marked terrace, pointing to a comparatively recent lowering of the surface of the water to the extent of about five feet. The loch is locally deep, and has a comparatively insignificant inflow. The nature of the outlet shows that the loch was held up to its former higher level by drift gravels, which were for a long time protected from erosion by a growth of peat;

sufficient outflow being afforded by percolation through the gravels and over the peat surface. The thick peat that covers the country between Forsinard and Kinbrace shows two buried forest growths. The upper layer consists of large pines and is found up to an elevation of 1,000 feet. The lower is of birch, and overlies the layer of black peat which forms the base of the deposit. A specimen of this black peat examined by Mr. Lewis of Liverpool University was found to contain sub-arctic plants.

The few striae and boulders foreign to the area observed by Mr. Macgregor in the Lairg district point to a movement of the main ice-sheet in a direction somewhat to the east of south, while the disposition of the conspicuous moraines around the foot of Loch Shin and in the valleys east and west of Cnoc Neill indicates a retreat of the ice towards the north-west. The numerous granite boulders of local origin in the drift around Lairg point to a later carry from the high ground to the north of the village.

The pre-glacial topography of the district is somewhat obscure. The upper part of Strath Fleet, now occupied by an insignificant burn, probably represents a part of the valley of an ancient consequent river by which the drainage basin of Loch Shin escaped eastwards at a very early pre-glacial period. The present loch no doubt occupies a portion, greatly over-deepened by glacial action, of the upper part of the same river valley.

### ECONOMICS.

At Dalmore, a mile west of Rogart, the granite has been largely quarried for building-stone and monumental purposes. The commercial value of the stone is greatly impaired by the occurrence of numerous dark, fine-grained, ovoid patches of basic material which are softer and consequently yield more readily to weathering than the surrounding more acid rock. This fact, together with the distance from the market, led to the abandonment of the quarry some years ago.

## *Perthshire and Inverness-shire.*

### HIGHLAND METAMORPHIC ROCKS.

The greater part of the ground surveyed by Mr. Carruthers between Loch Ericht and Loch Garry is occupied by siliceous schists, much granulitised, and with a fair abundance of finely disseminated black mica. At Creag na h' Iolaire, near the southern end of Loch Ericht, coarse micaceous bands are abundant.

It would appear that the deeply trenched hollow of Loch Ericht has not been entirely determined by the fault which runs S.W. across the Moor of Rannoch. The rocks along the eastern shore of the loch towards its southern extremity are not crushed, but a marked line of disturbance, accompanied by a belt of brecciated granulite over half-a-mile in breadth, can be followed up the Allt Ghlas, a tributary of the river Ericht, and enters Loch Ericht a short distance to the north of Coire Bhachdaidh Lodge. This dislocation is the northern continuation of the zone of crush which crosses the head of Loch Rannoch and passes through the Sloc na Creadha into Glen Lyon.

The further examination by Mr. Hinxman of the ground between the head of Loch Rannoch and Glen Lyon has shown that the high ridge extending southwards from Luban Feith a' Mhadaidh to Meall Buidhe is occupied by the series of altered sedimentary rocks—pelitic schists, limestone and quartzite—that were referred to in last year's Report as the probable representatives of a similar sedimentary series in the districts of Loch Leven and Glencoe. This may be briefly described as the Lochaber Series.

The different members of the group are repeated along the ridge by minor isoclinal folds, whose axes dip towards the south, the quartzite forming the highest part of Garbh Mheall. On the west side they are faulted against the Moine schists, each band being successively drawn into the zone of intense deformation which follows the line of the Sloc na Creadha fault. The relation of these sediments to the schists and granulites of Moine type by which they are surrounded on the north, east and south is somewhat obscure, but is probably, though not yet demonstrably, a discordant one, and the evidence suggests that the rocks in the area described above form a portion of a recumbent complex fold of the Lochaber Series.

## IGNEOUS ROCKS.

Evidence of the extremely irregular nature of the upper surface of the Moor of Rannoch granite intrusion has been obtained on Beinn Pharlagain in the Rannoch Forest. The granite and granite-schist plexus is exposed along the bed of the Allt Eigheach in the deep valley between Sron Leachd a' Chaorruinn and Beinn Pharlagain, where the solid granite is seen to pass beneath the schists which form the steep hillsides on either side of the glen. A mile and a half to the east the granite suddenly rises from the foot to the summit of Beinn Pharlagain, a vertical distance of over 1,600 feet. The schists which occupy the intervening space and form the western part of the mountain are cut off to the south by the Loch Ericht fault.

In the further area of Moor of Rannoch granite examined by Mr. Anderson, the planes of flow structure—indicated by the rude arrangement of the ferro-magnesian minerals and by the flattening of the basic segregations—are found to run roughly parallel to the northern margin. As the planes are also nearly vertical, this would seem to indicate that the massif may, in places, have vertical edges, as in the case of the Cruachan and Starav granite masses.

The north-easterly porphyritic dykes which pierce the granite decrease in number eastwards up the valley of the Blackwater. Many of the dykes with abundant felspar phenocrysts are cut by others more sparsely porphyritic. A quartz porphyry dyke, which for some distance follows the course of the river Etive, has been traced across the watershed between that river and the Blackwater to a point at least two miles beyond the further shore of Lochan na Salach Uidhre.

On the eastern shore of Loch Ericht, around Stob an Aonaich Mhoir, Mr. Carruthers has met with an irregular tongue of hornblende granite, about two square miles in extent, which is in places

rudely foliated. The foliation appears to have been produced before or during the consolidation of the magma, and affords no evidence that the intrusion took place before the movements that produced the foliation of the surrounding schists.

Dykes of pink porphyrite and felsite are abundant, and, as a rule, run in a north-easterly direction. To the south-west of Loch Garry several of these dykes have suffered a considerable lateral displacement along the line of a north-westerly fault.

Small basic intrusions, partly sheared, and apparently more of the nature of sills than of dykes, are also not uncommon. Their relation to the acid dykes and to the granite has not yet been determined.

### PLEISTOCENE AND RECENT.

The direction of the striae on the hill tops between Loch Ericht and Loch Garry show that during the earlier phases of the glaciation of the country the ice moved eastwards across the Loch Ericht hollow from the high mountain region to the west of that loch.

At a later period, when the level of the ice sheet had fallen, the Loch Ericht hollow formed a principal high-level outlet for the great *mer de glace* that covered the Moor of Rannoch.

The local indraught of the ice towards this outlet is well shown by the gradual divergence from east to N.N.E. of the striae on the ground between Loch Laidon and the foot of Loch Ericht. Further evidence of its passage in this direction is found in the over-deepened hollow that lies on the north side of Sron Smeur, beneath the truncated and glaciated spurs of Beinn Pharlagain, and in the fine terminal and lateral moraines which fill the mouth of the hollow and flank the sides of the enclosing hills.

Lochan Sroin Smeur, which occupies the centre of this hollow, affords a good example of a drift-dammed loch situated on the summit of a glacially-lowered col.

Further to the west, in the northern part of the Moor of Rannoch, Mr. Anderson finds from the trend of the moraines and the distribution of carried blocks, that the ice-movement during the later glaciation was eastwards up the valley of the Blackwater.

## 3. Shotts and Fauldhouse District.

Mr. C. T. Clough, M.A., District Geologist.
Mr. W. B. Wright, B.A. } Geologists.
Mr. B. Lightfoot, B.A. }

### COAL MEASURES.

The district revised by Mr. Lightfoot, between Shotts and Fauldhouse, is almost entirely covered with superficial deposits, no good rock sections being seen. Coal and ironstone have been worked over about half the area, whilst in the remaining ground bores are abundant, enabling the structure to be definitely ascertained. The field, on the whole, is a fairly flat one, and the

faults crossing it are nearly all parallel, and throw in the same direction. In the western portion, near Shotts Iron Works, the faults run approximately east and west, the largest having a downthrow to the north of about 15 fathoms and dying out in an easterly direction. In the eastern end the faults run north-west and south-east and throw down to the north-east. The largest disturbance, however, with a downthrow to the north of 40 fathoms, runs W.N.W. and dies out in a westerly direction. This fault lets in the highest coals of the area, the Blackband and the Benhar or Virtuewell, the latter of which is about 4 feet thick but is now entirely worked out to the crop.

The Blackband coal though thin is of good quality, and has been worked at Fallahill. More recently, an old shaft to the Benhar coal has been reopened to work it at Starryshaw. On the south side of the 40-fathom fault, the most extensive workings have been in the Slatyband Ironstone and in the Shotts Furnace Coal. Originally, the field was exploited for the Slatyband Ironstone, and numerous deep bores were put down. With the exception of the Furnace Coal the coals passed through in the bores were not then considered to be of much value, but the following were worked to some extent, chiefly in the Fallahill district, Ladygrange, Shotts Low,* Shotts Smithy,* Mill, Ball, Main and Crofthead. The field lying to the south and west was not regarded of sufficient value to warrant the sinking of separate shafts for the coals alone, and the coals mentioned above were only worked from the ironstone pits. During the last few years pits have been sunk to work the lower coals at Kepplehill, Stane and Knowton, the introduction of coal cutters having rendered the working more profitable than in former times. The metals and coals are found to be very variable, chiefly owing to the incoming of irregular masses of sandstone. A very good example of this irregularity is to be seen in the workings of the Kepplehill Coal Co. The Main Coal has a hard sandstone roof, and varies remarkably in thickness owing to the rolling character of the latter. Although the pavement is quite regular, there are peculiar "wants" in the coal itself: in the largest of these the coal is absent for a distance of about 70 yards, and at one side is much increased in thickness.

### INTRUSIVE ROCKS IN THE COAL MEASURES.

The step-like mode of transgression of whin sills described by Mr. Wright in the 'Summary of Progress' for the year 1908, p. 67, has been found by him to be of fairly common occurrence in the great whin of Torrance, south of Hillend Reservoir. Steeply-inclined or stepped-chilled margins have been observed near Barblues, east of Lilly Loch, to the south-west of Cairny and near Forrest. These plunging margins do not all run in the same direction, the two first mentioned facing north, the third a little south of west and the fourth a little north of east. In some cases, bores put down close to scarps of this nature show a rapid transgression across the metals. The plunging face at Forrest can

* In Ironworks district only.

be traced a quarter of a mile south of Forrestfield Station, on the end of the remarkable east and west ridge known as the Kames, which is thus proved not to be a dyke.

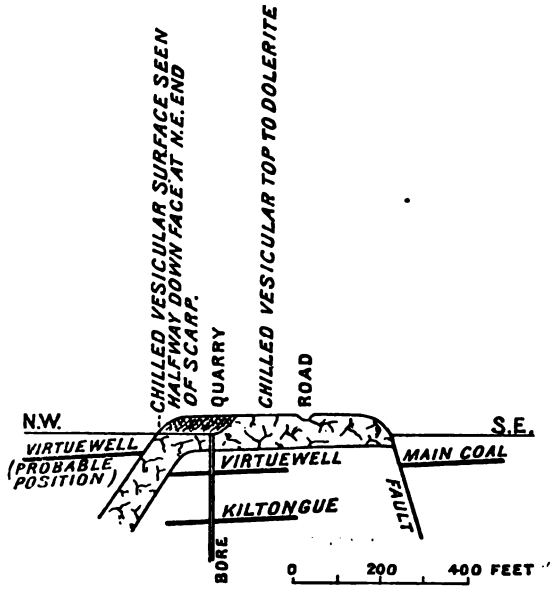


Fig. 4. Diagrammatic section across plunging dolerite sill at Browniesidecraig, Clarkston.

Another well-defined case of a plunging whin has been observed at Brownieside, north of Clarkston. This whin has a steep face to the north on which remnants of the chilled vesicular surface are preserved. The Virtuewell Coal which outcrops to the north of Brownieside, and there lies above the whin, is transgressed by the latter at Browniesidecraig. This is proved by the fact that a bore sunk through the whin shows the same coal beneath it at the last-mentioned locality. The relations are exhibited diagrammatically in Fig. 4.

## PLEISTOCENE.

An interesting feature in the area revised by Mr. Lightfoot is the eastern end of an extensive series of sand and gravel mounds stretching down the valley of the South Calder Water to Allanton. Good sections of these mounds are seen in sand-pits, one of which is still being worked, in Stane village. The mounds are composed of rounded pebbles and sand with fragments of coal and shale, and the material is evidently derived from the washing of boulder clay. Miners state that coinciding with the line of these mounds is a series of "wash outs" in the coals and metals of the area. Such "wash outs" are, however, not always associated with a moundy surface, as is at present seen in Braehead mine, near Fauldhouse Station, where, at a depth of 5 fathoms, a "wash out" is filled with sand and gravel identical in character with that forming the mounds at Stane.

### 4. Kilbride and Carluke District.

Mr. L. W. Hinxman, B.A., District Geologist.
Mr. C. B. Crampton, M.B., C.M.
Mr. E. M. Anderson, M.A., B.Sc.
Mr. R. G. Carruthers.
Mr. M. Macgregor, M.A., B.Sc. } Geologists.

The revision of the Douglas coal-field was begun by Dr. Crampton, a part of the East Kilbride basin was revised by Mr. Carruthers and the country round Carluke by Mr. Hinxman. The coal-field areas in the neighbourhood of Bathgate were re-examined by Mr. Anderson and Mr. Macgregor.

#### Calciferous Sandstone and Carboniferous Limestone Series.

*District of East Kilbride.*—Results of considerable stratigraphical interest have attended the revision of this district by Mr. Carruthers. This area intervenes between that occupied by strata of similar age in the typical district of Hurlet, some five or six miles to the north-west, and the important limestone series of Carluke, about 12 miles to the east.

The exact determination of the various horizons is therefore of importance in its bearing on the interpretation of the limestone series along the southern side of the Lanarkshire Coal-field.

The sediments in the area under consideration have a simple synclinal arrangement. They rest upon the volcanic rocks of the Cathkin and Busby Hills and belong chiefly to the Carboniferous Limestone Series, together with a variable thickness of the underlying Upper Calciferous Sandstone strata.

In the Explanation to Sheet 23, certain correlations with the Carluke district were made, but no comparison with the typical Hurlet sequence seems to have been attempted. This is not surprising, for at first sight the succession in the two areas appears to be strikingly different. The closer investigation permitted by the present revision has, however, resulted in a satisfactory correlation. The difference can be largely explained by the extensive overlap of the sediments on to the volcanic rocks. For this reason, several hundred feet of strata, including limestones and coals, which are found beneath the Hurlet Seam in the Hurlet and Paisley district, are absent over the western part of the East Kilbride basin. To the eastward, however, the overlap rapidly diminishes, and these beds reappear along the banks of the Calder, near Basket.

The gorge of the Calder, over four miles in length, cuts right across the centre of the basin, affording one of the finest natural sections of Carboniferous strata in the West of Scotland. The detailed examination of this section is not yet completed. In the meantime it may be said, that, with the exception of some unimportant strata cut out by small faults, a complete sequence of the sediments of the basin is here exposed. Representatives have been met with of every member of the Hurlet sequence (with the exception of the Hurlet coal) from the top Hosie Limestone—the Calderwood Cement—down to the Lady Ann Coal. There is also

strong reason for regarding the Main Limestone of the East Kilbride district, now worked at Thorntonhall, as the equivalent of the Blackbyres Limestone of Hurlet.*

The discovery has also been made in the Calder section of two beds containing a "Pendleside fauna," with goniatites and lamellibranchs belonging to the gentes of *Posidonomya becheri* and *Pterinopecten papyraceus*. Both occur in the Calciferous Sandstone Series, below the Main Limestone. The lower rests upon a coal which can be correlated with the Lady Ann Coal of the Hurlet district.

Three horizons for this peculiar fauna have therefore now been found in the Calder Section. The third, which has been known for many years, is much higher up in the sequence, and occurs in the Carboniferous Limestone Series, just over the Calderwood Cement—or top Hosie Limestone of Hurlet.

The delimitation of the small area of workable coals of the Middle Limestone group found in the centre of the basin is proceeding, and will form a new feature in the revised map.

### CARBONIFEROUS LIMESTONE SERIES.

*Carluke.*—The numerous pits and open-cast workings in which the limestones and ironstones of this series were raised at the time of the original survey of the Carluke district, afforded a number of sections, most of which are now no longer exposed.

It has, however, been found possible to identify the Main Limestone and Coal—the principal seam wrought in the area—with the Hurlet seam. The former is a hard encrinital limestone 4 to 6 feet in thickness, and rests upon dark alum shales and a coal from 14 to 20 inches thick. Beneath this coal is a thick fireclay containing rounded irregular limestone concretions, similar to those found beneath the Hurlet Limestone at Baljaffray, Hurlet and East Kilbride. The Main Limestone in this district is invariably accompanied above by a 2 foot calmy band, from which it is separated by 8 to 18 feet of dark shales with several bands of clayband ironstone.

The limestones of the Hosie group are well developed, and five, or sometimes six, distinct beds, 2 to 6 feet in thickness, occur within an average distance of 18 fathoms. Between the lowest of these, the Foul limestone, and the Birkfield—a thick, highly fossiliferous seam—are found the Raesgill beds, a series of black shales with numerous clayband ironstones, at one time largely wrought around Carluke.

The highest Hosie or Calmy limestone, which is well exposed at Hallcraig, can, together with the two Kingshaw bands, be satisfactorily correlated with the Calderwood Cement and two succeeding limestones in the Calder section at East Kilbride.†

The coals and ironstones of the Middle Group of the Series are but poorly represented. The Gas Coal near the base of the group, though reaching 9 inches at Orchard, is generally too thin to be profitably worked, while the Tower and Upper and Lower Carluke

* See a brief notice of this bed in 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), 1906, p. 125.

† The correlation of this Calmy Limestone with the Calderwood cement was first made by (Professor) James Geikie in his original survey of the district. See Expl. Sheet 23 (*Mem. Geol. Surv.*) 1873, p. 29.

coals, in the Possil position, do not exceed 2½ feet in thickness. The only workable ironstones are the clay-bands known as the "Maggie Bands," between the Gas and the Tower coals.

Of the Upper Limestones only the Gillfoot, presumably on the horizon of the Orchard Limestone of the Glasgow district, is now exposed.

The structure of the ground south of the Castlehill fault is somewhat complicated. The beds undulate at low angles and are thrown into a series of shallow troughs or basins, which are further broken by numerous east-and-west and N.W.-S.E. faults. The outcrops of the coals and limestones have consequently a sinuous course and are constantly shifted by the faulting.

### COAL MEASURES.

*Carluke.*—The coal measures in the area immediately north of Carluke occupy a shallow basin or trough, whose southern extremity is truncated by a powerful east-and-west fault, by which strata slightly above the Kiltongue Coal in the centre of the basin are thrown down against the Upper Limestones of the Carboniferous Limestone Series. The throw of this fault appears to increase towards the east, as within a short distance of Carluke it brings pebbly sandstones, high up in the Millstone Grit, against the upper seams of the Lower Limestone group.

The principal coals represented in this part of the basin, and now or at one time raised at the Castlehill colliery, are the Kiltongue, the Shotts Furnace or Upper Drumgray—locally known as the Ball Coal—the 4 foot or Mid Drumgray, and the Smithy Coal or Lower Drumgray. The lower seams are mostly thin and so far have not been wrought. A seam 2 ft. 9 in. thick, 18 fms. below the Smithy Coal, is correlated with the Mill Coal of the Slamannan district; and a thinner coal, 14 fathoms below the Mill, may represent the Armadale Main.

The slatyband ironstone was formerly mined along the crop near Bowridge, but has not been recognised in bores put down in the centre of the basin.

In the ground to the east of Armadale, revised by Mr. Anderson, the Upper Drumgray coal was formerly wrought under the name of the Splint, while the Lower Drumgray, which is still being raised, is known as the Coxrod. The relation of the latter to the lower coals of the Armadale sequence is shown by the following table :—

| | Fms. | Ft. | In. |
|---|---|---|---|
| Coxrod Coal, with fireclay parting ... ... ... | | 3 | 0 |
| Strata ... ... ... ... ... ... | 8 | 0 | 0 |
| Upper Cannel Coal or Oil shale (Shotts Gas Coal) ... | | 3 | 0 |
| Strata ... ... ... ... ... ... | 16 | 0 | 0 |
| Mill Coal ... ... ... ... ... ... ... | | 2 | 0 |
| Strata ... ... ... ... ... ... | 12 | 0 | 0 |
| Ball Coal ... ... ... ... ... ... ... | | 2 | 0 |
| Strata ... ... ... ... ... ... | 5 | 0 | 0 |
| Main Coal ... ... ... ... ... ... | | 3 | 6 |
| Strata ... ... ... ... ... ... | 10 | 0 | 0 |
| Colinburn Coal ... ... ... ... ... ... | | 2 | 0 |
| Strata ... ... ... ... ... ... | 1 | 0 | 0 |
| Torbanehill or Boghead Parrot Coal ... ... ... | | 0 | 6 |
| Strata ... ... ... ... ... ... | 1 | 0 | 0 |

Slatyband Ironstone.

The area of Millstone Grit and Lower Coal Measures revised by Mr. Macgregor to the south-west of Bathgate, forms part of the eastern margin of the wide basin of Carboniferous strata which occupies the centre of Sheet 31. The beds at Boghead and Durhamtown dip steeply to the west, but towards Whitburn the strike swings round westwards, with a considerable flattening of the angle of dip. The ground is traversed by a number of N.W.-S.E. faults, one of which displaces the outcrops for a distance of half-a-mile. A dolerite dyke, 30-40 feet in width, crosses the area from east to west, burning the coal for a short distance on either side into a loose cindery mass.

## ECONOMICS.

*Coal.*—Of the Limestone Coals the only seam wrought at the present time in the Carluke area is the Carluke Smithy, Second, or Lower Coal, which is raised for local use in a shallow pit at Carluke and in a mine near Hallbar Tower. The seam averages 2 feet in thickness and affords a second-class house coal. In the Carluke workings a 2-inch band of very hard and bright cannel coal, almost of the quality of jet, overlies the seam.

The Coal Measure coals now being worked at Castle Hill Colliery, Carluke, have already been referred to. Of these, the Kiltongue and Upper Drumgray are good steam coals; the Mid Drumgray and Smithy, house coals.

It is interesting to find that the Torbanehill coal is still wrought in connection with the overlying fireclay to a small extent near Armadale, where, at the present position of the working faces, it has a thickness of 0 to 8 inches.

In the ground close to Armadale, examined by Mr. Anderson, the Mill seam affords a good household coal, while the Main and Ball are mainly used as steam coal. Further to the south, Mr. Macgregor reports that the two latter seams are worked both as steam and house coals.

*Ironstone.*—Clayband ironstone ore has at one time or another been raised from three different horizons in the Carluke district:—(1) the shales overlying the Main or Hurlet Limestone; (2) the Raisgill beds, between the Foul and Birkfield Limestones, and (3) the Maggie Bands, between the Gas and Tower Coals. The Raisgill Ironstones were largely wrought up to about the year 1882, but the industry is now quite extinct in the district.

The seam of nodular clayband ironstone which overlies the Ball coal is worked and calcined at the pit-head at the Northrigg Colliery, 2 miles S.S.W. of Bathgate.

*Bricks and Tiles.*—Composition pressed and moulded bricks are made at Hallcraig and Braidwood from ground blaes from the waste heaps of the old ironstone workings. Laminated plastic clays, probably of glacial origin, are also employed at Hallcraig and Carluke in the manufacture of bricks and tiles. The fireclay beneath the Smithy Coal at the Castle Hill Pit is used for the large draining tiles produced at the Braidwood Works.

At the Nellfield Brick and Tile Works a very hard red brick with blue "flashing"—either as a skin of varying thickness or blue

throughout—is made from crushed red marl and marly sandstone. The exact geological position of these beds has not yet been determined, but they are probably included in the Calciferous Sandstone Series.

Several seams of fireclay of economic value occur in the lower part of the Coal Measures near Armadale. The lowest of these, which forms a constant feature beneath the Colinburn Coal, is of superior quality and is used for firebricks. Other fireclays are wrought immediately above the Main Coal and below the Ball Coal. A thick clayey stratum, just above the Upper Cannel Coal, is worked open-cast, and mixed with a little boulder clay for composition bricks. The highest seam occurs as a parting in the Lower Drumgray Coal of the Armadale district. It is a plastic clay and is used in the manufacture of sanitary pipes.

*Road Metal.*—The road metal used in the Carluke district is a very hard fine-grained bright-red felsite, of excellent quality for this purpose. It is at the present time entirely obtained from quarries on Cairngryfe Hill, near Petinain.

## III.—PETROGRAPHICAL WORK.

During 1909 petrographical investigation was carried on in connection with all the districts surveyed, but principally Cornwall, South Wales, the Scottish coal-fields, and the Highlands. Some of the results are incorporated in the reports of the field geologists in this Summary, and the remainder will appear, so far as they are of importance, in the Memoirs which are being prepared for the press.

In the Summary of Progress for 1908 (p. 44) a brief description was given of some types of basic nepheline-rocks that had recently been found in Scotland, including essexites, theralites, nepheline-teschenites, and nepheline-basalts. During 1909 several additional occurrences of nepheline-rocks have been discovered, both in England and in Scotland, and as these rocks are of general interest, apart from the geology of the districts in which they occur, we may give a few particulars regarding them.

*Nepheline-basanite.*—In the northern part of Staffordshire there is a well-known dyke which is exposed in several quarries at Butterton and Swynnerton.* Specimens taken from the centre of this dyke in the quarry at Butterton Hall Park prove to be nepheline-basanite in excellent preservation. The rock consists of olivine, augite, plagioclase-felspar and nepheline. At first glance a microscopic section of this dyke is much like a fresh and rather fine-grained olivine-dolerite. The abundant olivine is microporphyritic and not easily detected in the hand-specimens without the aid of a lens. Purplish-brown, zonal augite appears in small cumorphic crystals, but seldom is porphyritic. Minute laths of polysynthetic felspar are numerous in the groundmass; from their extinction angles and refractive indices they seem to belong to

* The Geology of the North Staffordshire Coal-field' (*Mem. Geol. Surv.*). p. 190.

labradorite. In addition to these, a clear transparent mineral with low double refraction and a distinct cleavage fills up the interstitial areas left after crystallization of pyroxene and felspar. This mineral has the cleavage and refractive index of nepheline, and stains readily; it is entirely undecomposed, and in this respect no other nepheline-bearing rock in Britain can compare with it.

For a long time the Wolf Rock phonolite has been the only English rock which is known to contain nepheline, and the addition of a basic type to the list is of some interest. The Wolf Rock is generally considered of Tertiary age; the Butterton dyke has a north-north-west trend and cuts and bakes the Keuper Marls. It must be post-Triassic, and may with much probability be regarded also as Tertiary.

*Nepheline-basalts.*—At the extreme north point of Scotland on the promontory of Duncansby Ness, and less than a mile from John O'Groat's, there is a small volcanic neck, which was discovered by Sir Archibald Geikie.* The materials occupying this neck are of a remarkable character, and consist of greenish tuff with basalt-bombs, large pieces of sandstone, gneiss, granite and porphyry. Mixed with these are lumps of augite as large as an orange, and olivine-nodules weathered to serpentine and carbonates. The tuff is veined by a fine dark basalt, which is charged with minute angular pieces of baked sandstone; the inclusions occur in immense numbers and are often partly dissolved by the basic magma.

The black basalt of the dykes is by no means fresh, and a microscopic section shows weathered olivine, brown augite and decomposed nepheline, but no felspar. The nepheline forms rather large and irregular plates, but occurs also in perfect hexagonal prisms, and stains readily. It is especially abundant in certain nodular masses which are apparently authigenic or cognate 'xenoliths.'

The age of this basalt is not clear, for it has little resemblance to the Devonian lavas of the Orkneys and Shetland. Monchiquite dykes, however, occur near Dunnet in Caithness; and though they do not show nepheline, they resemble the nepheline-basalt in several respects. These dykes belong to the same series as the camptonites and monchiquites of the Orkneys, which may be Tertiary, though there is no good evidence to establish this.

Another nepheline-basalt in better preservation was found by Mr. W. B. Wright in a small ash-neck which pierces the schists in Coiré na Ba, about a mile north of Kinlochleven, and seven miles from Ballachulish. In this rock also there is much olivine and purplish-brown augite but no felspar; dark brown biotite is present in irregular plates but is not abundant, and the groundmass contains large nepheline crystals (up to a millimetre broad) which are poikilitic with olivine, augite and iron-oxides. The nepheline has the characteristic double refraction and cleavage, and is exceptionally fresh but never idimorphic. Its presence was first observed by Mr. H. B. Maufe. Some analcite occurs also in this rock, but it does not seem probable that any vitreous base was originally present.

* 'On the Old Red Sandstone of Western Europe.' *Trans. Roy. Soc. Edin.*, vol. xxviii., 1879, p. 406.

The nepheline was certainly of later crystallization than the other minerals. As two nepheline basalts were reported from East Lothian in the Summary of Progress for 1908, there are now four known occurrences of these rocks in Great Britain. The geological age of the Coiré na Ba neck is quite uncertain.

*Nepheline-Monchiquites.*—In Argyll and Mull there is a great development of dykes, which have a general north-west trend, and are believed to be of Tertiary age. It has been known for some time that certain north-west dykes cut the east-and-west dykes of quartz dolerite, which are late-Carboniferous. Many distinct kinds of rock are found in these dykes, such as olivine-dolerite, quartz-dolerite, tholeiite, keratophyre, hypersthene-andesite, camptonite and monchiquite; and the assemblage is so varied, and in some respects so unusual, that caution is necessary in assuming that they all belong to the same epoch or have come from one magma.

Among these dykes nepheline-rocks have now been proved to occur. In the south of Mull, at Ardachy and at Carraig Mor, there are two dykes of fine-grained nepheline monchiquite. Like the nepheline-basalts above-mentioned they consist of olivine, purple augite, and nepheline, with a subordinate quantity of biotite and iron-oxides. The nepheline is interstitial, usually much decomposed, and shows no crystalline outlines. These rocks have been placed among the monchiquites because they are found in intimate association with camptonites, and because they contain many of the small rounded "ocelli" which are so characteristic of the monchiquites.

At Kilchattan, in the island of Colonsay, there is a north-west dyke which is of striking appearance because it carries large black crystals of perfectly fresh augite, hornblende and biotite, often more than an inch in length. The ground mass of this rock consists of purple augite, biotite, and weathered nepheline. Another distinctive feature is the absence of olivine, and this places the rock in the sub-group of monchiquites which have been called ouachitites. Nepheline-bearing monchiquites are of great rarity, but some have been described from Madagascar by Professor Lacroix.*

The camptonites and monchiquites of Colonsay and Mull are not closely connected with the ordinary types of olivine-basalt of the west of Scotland. There are, however, many transitions between the camptonites and a group of dolerites rich in analcite which occur in the same districts. These analcite-olivine-dolerites contain much purple augite and are sometimes perfectly ophitic. They seem to have affinities with the theralites and teschenites, and to mark their individuality, it has been decided to give them a distinctive name. They have been called *crinanites*, from Loch Crinan, which is almost in the centre of their area of distribution. Further particulars respecting these rocks, with analyses, will be found in the memoirs on Colonsay (Sheet 35) and Knapdale (Sheet 28), which are in the press.

* 'A. Lacroix. 'Matériaux pour la Minéralogie de Madagascar.' Nouvelles Archives du Museum, vol. iv., 1902, p. 141.

# IV.—PALÆONTOLOGICAL WORK.

## (1) England and Wales.

The work of dealing with the fossils collected during the year, which bear upon the current work of geological mapping, has been chiefly undertaken by Dr. Ivor Thomas, but many specimens from the Survey and Museum collections have been reported upon by the following specialists who are not members of the staff:—Mr. S. S. Buckman, Miss Elles, Dr. Wheelton Hind, Dr. R. Kidston, Mr. P. Lake, Dr. C. A. Matley, Mrs. Shakespear, and Mr. H. Woods.

In the early part of the year Dr. Thomas gave further attention to certain new Devonian fossils from Devon and Cornwall, and his results have been published in communications to the "Geological Magazine." He has continued his work on the Carboniferous Productids, and has examined many type-specimens as well as other materials in public and private collections. In connection with this work he visited Derbyshire in order to collect examples of *Productus*, and observe the distribution of some of the species in localities where certain type-specimens were formerly obtained. Amongst other results, it becomes evident that the group of *Productus elegans* comprises several species.

In connection with Carboniferous palæontology, and the efforts now being made to elucidate the zonal sequence in the Carboniferous rocks of different districts, Dr. Thomas has been led to attempt a revision of the genera comprising the sub-family Orthotetinæ. This has appeared the more necessary in view of the results of the recent work by Dr. G. H. Girty, and the fact that the systematic and critical study of these forms has been unduly neglected in this country. Dr. Thomas's investigation has well borne out the importance of internal septa and so-called dental plates in a generic classification. It may be anticipated that this work and that on the Productidæ will show the significance of many of the representatives of these genera in the study of the zonal succession.

One or two further points of interest in connection with the palæontology of the Carboniferous Limestone Series may be mentioned. Some remains of sponges which Dr. G. J. Hinde has pronounced to be probably new to Britain have been found in the Pembrokeshire coast-section at a horizon in $C_2$—$S_1$. *Dibunophyllum* and *Cyathaxonia rushiana* Vaughan have been collected at this same zonal position in Pembrokeshire. These forms, which have been identified by Mr. R. G. Carruthers, have hitherto only been known from the strata in D.

Dr. Kitchin has continued his work on the palæontological materials obtained from the deep-seated Mesozoic rocks passed through in some shaft-sinkings and borings in Kent. Some of the points of interest which have arisen in the course of this work were noted in the 'Summary of Progress' for 1908.

A considerable amount of revision of nomenclature in the Museum cases has recently been carried out, and in this connection Mr. Allen has completed the renaming and rearrangement of the Oolitic lamellibranchs and gasteropods, and the preparation of a corresponding manuscript catalogue. Some of the more interesting additions to the Museum collection have included specimens of

*Palaeoxyris*, given by Dr. L. Moysey, some examples of *Pygocephalus cooperi* Huxley, which had been figured by Dr. Henry Woodward (*Geol. Mag.*, 1907, pl. xviii), presented by Mr. H. W. Hughes, and some excellently preserved figured specimens of graptolites from the Llandovery rocks of Cardiganshire, the gift of Prof. O. T. Jones.

Mr. J. Pringle paid a visit in October to the boring at Stowell, Somersetshire, where, through the kindness of Mr. W. Phelps, C.E., he was enabled to examine the cores which had been procured since he was there in the previous year. He collected many fossils from the Inferior Oolite and Yeovil Sands which had been passed through, and an account of the information he obtained is published in Appendix I.

The following specimens in the Museum have been figured and described during the year :—

### In the Palæontographical Society's Volume for the Year 1909.

*Cretaceous Lamellibranchia of England.*

By Mr. Henry Woods, M.A.

Martesia constricta (*Phill.*), pl. xxxviii, figs. 7, 10.
„ prisca (*J. de C. Sow.*), pl. xxxviii, fig. 11.
Teredo gaultina *sp. nov.*, pl. xxxviii, fig. 21.
Thracia carinifera (*J. de C. Sow.*), pl. xl, figs. 12, 13.
„ rotundata (*J. de C. Sow.*), pl. xxxix, fig. 10.
„ sanctacrucis *Pict. and Camp.*, pl. xl, figs. 5, 6.
„ sp., pl. xl, figs. 7–9.
Pholadomya speetonensis *sp. nov.*, pl. xli, fig. 4.
„ cordata *Tate*, pl. xlii, fig. 2.
Cuspidaria sabaudiana (*Pict. and Camp.*), pl. xliii, fig. 6.

### In the Quarterly Journal of the Geological Society. Vol. LXV.

By Mr. O. T. Jones, M.A., B.Sc.

Monograptus atavus *sp. nov.*, p. 532.
„ rheidolensis *sp. nov.*, p. 534.

By Mrs. J. Longstaff.

Loxonema cornubicum *sp. nov.*, pl. x, fig. 2.
„ perneri *sp. nov.*, pl. xi, fig. 1.
„ „ *var.* dudleyense *var. nov.*, pl. xi, fig. 3.
„ reedi *sp. nov.*, pl. xi, fig. 4.
Stylonema hibernicum *sp. nov.*, pl. xi, fig. 8.
Hormotoma inceptor *sp. nov.*, pl. xi, fig. 10.

### In the Geological Magazine, Vol. VI, 1909.

By Dr. Ivor Thomas, B.Sc.

Phacops (Trimerocephalus) pentops *sp. nov.*, pl. iii, figs. 1–4.
Allorisma concinna *sp. nov.*, pl. iii, figs. 5, 6.
Phacops (Trimerocephalus) anophthalmus *Frech*, pl. vii, fig. 1.
„ „ cryptophthalmus *Emmr.*, pl. vii, figs. 2, 3.
„ „ tripartitus *sp. nov.*, pl. vii, figs. 4, 5.
Proetus dunhevidensis *sp. nov.*, pl. vii, fig. 6.
„ spp., pl. vii, figs. 7–9.
Dechenella ussheri *sp. nov.*, pl. vii, fig. 10.
Phillipsia minor *H. Woodw.*, pl. vii, fig. 11.
„ *cf.* minor, pl. vii, figs. 12, 13.
„ sp., pl. vii, fig. 14.

## (2) Scotland.

In connection with the current Survey work, fossils have been collected from the Old Red Sandstone of Caithness, the Carboniferous areas of Central Scotland, and the Jurassic rocks of Mull. Special collections were also made from the Silurian rocks of Ayrshire and from Post-Tertiary deposits in Argyllshire. The fishes, the plants, the lamellibranchs and the Post-Tertiary fossils have been named by Dr. Traquair, Dr. Kidston, Dr. Wheelton Hind, and Dr. Th. Scott respectively.

The Old Red fishes collected in Caithness by Mr. Tait have been examined by Dr. Traquair, who recognised the following species :—

| | |
|---|---|
| *Cheiracanthus latus* Eg.<br>*Cheiracanthus murchisoni* Ag. | Halkirk, Thurso River, ¼ mile W. of Halkirk Bridge. |
| *Coccosteus decipiens* Ag. | Between Skyoll and Selchie Head. Small quarry in field between the farms of N. Calder and Lower Sour, 2 miles N.W. of Halkirk. Stemster Quarry. |
| *Coccosteus minor* Mill. ... | Small quarry on cliff edge midway between Longoe Skerries and St. John's Point. S.E. shore of Murkle Bay, in S. shore of Dunnet Bay. On shore W. side of stream which flows northwards past Barrogill Cas, Mey. Thurso Bay on shore N. of Pennyland. |
| *Diplacanthus striatus* Ag. | Halkirk, Thurso River, ¼ mile W. of Halkirk Bridge. |
| *Dipterus macropterus* Traq. | John o' Groats, 135 yards E. of Hotel. |
| *Dipterus valenciennesi* Sedg. & Murch. | On shore between Staxigoe and Papigoe. Between Skyoll and Selchie Head. Shore at Methow Hillock, ¼ mile E.S.E. of Clairdon Head. |
| *Glyptolepis paucidens* (Ag.) | Skirsa Head quarry. S.E. side of Tang Head, between Harrow and Skarfskerry. Murkle, about midway between E. Murkle and battery. |
| *Homosteus milleri* Traq. | Small quarry on top of cliff on N. side of Samuel's Goe. E. side of main road, Auckingill. Shore on seawards side of mill at Scarfskerry. |
| *Mesacanthus sp.*... ... | E. shore of Murkle Bay in S. shore of Dunnet Bay. Halkirk, as above. |
| *Microbrachius dicki?* Traq. | John o' Groats, as above. |
| *Osteolepis microlepidotus* Pander. | In loose blocks in bed of small stream, ¼ mile N.W. of Ha' of Duran, 3 miles S. of Castletown. |
| *Thursius macrolepidotus* (Sedg. & Murch.) | Quarry on S. side of road, ¼ mile E. of Auchunabust, and fully 2 miles E. of the church at Reay. Brims Ness, 6 miles N.E. of Reay. |
| *Thursius pholidotus* Traq. | Quarry for road metal, at the Baptist Chapel, Nybster. Old quarries at Syster, 5 miles E.N.E. of Castletown, and 1 mile N.E. of L. of Hailan. Small quarry on cliff edge, midway between Longoe Skerries and St. John's Point. S.E. shore of Murkle Bay. Thurso Bay, on shore N. of Pennyland. |
| *Tristichopterus alatus?* Eg. | John o' Groats, 135 yards E. of Hotel. |

A large proportion of the Carboniferous fossils were collected from the cores of bores, or from localities specially visited in order to ascertain the position of strata met with in bores. The records thus obtained may at some future date prove of value in zonal work,

and the following points, bearing more especially on the distribution of the fauna of the Upper Limestones and base of the Millstone Grit, may be mentioned here :—

In connection with an enquiry of economic nature Mr. Tait collected fossils from the neighbourhood of Dollar, Clackmannanshire; and from the bed mapped as "Vicar's Bridge Limestone," half a mile south of Dollar, a suite of lamellibranchs was obtained and submitted to Dr. Wh. Hind. They include *Chaenocardiola footi* (Baily), a new record for Scotland, and proved to belong to the fauna of North American facies which Dr. Hind has shown to be a characteristic feature of the base of the Millstone Grit in Central Scotland. The discovery is interesting as it proves that conditions suitable to the development of the North American fauna still existed in a north-easterly direction, and it is hoped they will be traced still further east, in Fife. Equally important is a discovery which seems to show that certain members of this peculiar fauna already existed before Millstone Grit time: *Prothyris elegans* Meek and ? *Protoschizodus curtus* (M. & W.), were observed among fossils collected from the cores of a bore near Stirling, from a position which is referred to the Index Limestone. Such an isolated occurrence is sufficient to show that it is not necessary to look to immigration in order to explain the peculiar—Upper Carboniferous—character of the Millstone Grit fauna, but rather that, in part, at least, it was sparingly represented in the Upper Limestones. Thus it may well be that the change between the Lower Carboniferous and the Upper Carboniferous molluscan faunas began to take place during Upper Limestone time. This assumption is supported by the recently discovered fact that in Ayrshire, quite fifty miles S.W. of the locality referred to above, a somewhat analogous character is exhibited by the brachiopods. The limestone quarries of Shield, near Cumnock, and of Bowertrapping, near Dalry, have yielded specimens of a species of *Meekella*, a genus which, with a single doubtful exception, is typically Upper Carboniferous both in America and in Russia. Careful search has failed to reveal the presence of any of these species in the Lower Limestone group, so that, were they more generally distributed in the Upper Limestones, they would be of great economic importance as "index fossils" of that group.

It might be argued that the presence in the Upper Limestones of species not found below, could be used to establish a zone comprising the Upper Limestones, and constituting a passage to the Upper Carboniferous rocks. But in order to establish such a zone on a sound basis, it will be necessary to obtain a larger number of the species used as zonal forms, together with a knowledge of their phylogenetic relations to pre-existing species.

Mention has been made from time to time of the narrow vertical range of *Edmondia punctatella* (Jones). This peculiar lamellibranch has been found in its usual position immediately below the Calmy Limestone in the cores of a bore near Plean, Stirlingshire; the horizontal extension of the Punctatella Bed is thus considerable, since it is known as far west as Dalry in Ayrshire.

The revision of some fossils to be incorporated in the fossil list of sheet 32 Memoir disclosed an interesting point touching the marine fauna of the Calciferous Sandstone in Midlothian. From a bed situated low down in the Calciferous Sandstone ¼ mile N.E. of Carlops, Messrs. Macconochie and McVey obtained a suite of fossils indicating normal marine conditions of moderate depth. Since the fossils hitherto obtained from the lower portions of the Calciferous Sandstone in Midlothian belong principally to species of lamellibranchs, *Orthoceras*, *Bellerophon*, *Lingula*, &c., the absence of hinged brachiopods and of corals did not permit of comparison with the zonal forms of Dr. Vaughan's classification. But the bed near Carlops yielded, besides lamellibranchs, specimens of *Productus*, *Camaratoechia*, *Seminula?*, *Fenestella*, and remains of a branching coral. The *Productus* bears such a striking resemblance to the *P. burlingtonensis* of the Tournaisian beds of the south-west of England that it is difficult to reconcile its presence with that of the coral, which is *Lithostrotion junceum* (Flem.), thus pointing to a Visean age for the beds. In view of this conflicting evidence one might hesitate to assign a definite horizon to this assemblage of fossils, but, since *Lithostrotion* is a widespread genus not known in Britain below the Visean, the stronger evidence seems to be in favour of a correlation with the Visean. At the same time, the presence of a *Productus*, identical with, or at least closely allied to, *P. burlingtonensis*, suggests an early period of Visean time, and the persistence of this species in a higher horizon than is the case in England.

The main results of the examination of the Mesozoic fossils collected in Mull have been set forth in the chapter dealing with the stratigraphy of the south-east corner of that island. Attention may, however, be drawn here to the interesting characters exhibited by the Lower Oolites. They are represented by hard sandy limestones characterised by a general assemblage of fossils which agrees very well with that of the Lower Oolites in the typical districts of England, though geographically so remote from them. This is specially the case with the ammonites, which give a striking illustration of the practical value of Mr. Buckman's work, his fine subdivisions enabling one to estimate the age of a bed from the stage of development of its ammonites. The lowest bed belongs to the Scissi Hemera and is characterised by *Lioceras partitum* S. Buckman, and, locally, by the remarkable abundance of a *Rhynchonella*, *Rh. subdecorata* Dav. Owing possibly to practical difficulties inherent to the hard nature of the rock, no fossils characteristic of the two succeeding zones (*i.e.*, of *Ludwigia murchisonae* and of *Brasilia bradfordensis*) were obtained, but the presence of *Ludwigella cornu* (S. Buckman) and *Ludwigella concava* (J. Sow.) prove the continuation of sedimentation during the Concavi Hemera. Fossils of the Discitae Hemera include a number of ammonites which, though not yet specifically determined, have reached the stage of development characterising this Hemera. Sedimentation proceeded evidently very slowly and uniformly during the lapse of time comprising these two Hemerae, for it is impossible in the field to assign to them two well-differentiated

zones. Grateful thanks are due to Mr. Buckman for checking some of the identifications on which the above correlations are based.

Although not strictly within the scope of last year's work, it is desirable to take this opportunity of referring to the identification of Radiolaria in cherts from the Eastern border of the Highlands. At the end of 1908 Dr. Peach re-examined some specimens of chert which Mr. Clough had collected many years ago from the Metamorphic rocks in the Aberfoyle area. Dr. Peach's opinion was that these specimens contained Radiolaria in the solid. The specimens were subsequently submitted to Dr. G. J. Hinde, F.R.S., who reported that ". . . the minute dumb-bell objects which are present in great numbers on the surface of the rock which has been split open, may be accepted as casts of radiolaria, although there is no conclusive proof that they possessed a porous test. With regard to size and form, these forms may be compared with undoubted fossil radiolaria from palaeozoic and mesozoic rocks, but until the characters of the test can be ascertained the degree of relationship will remain problematical." Thin slides were then made and submitted to Dr. Hinde who reported that: "In many of these bodies there were traces of a definite external test, now replaced by some iron compound, and though no pores could be seen there were some projecting points which might indicate their former presence."

## V.—MUSEUM OF PRACTICAL GEOLOGY.

During the year a new guide has been published to take the place of the "Handbook to the Museum," price 6*d.*, which has been rendered obsolete by the removal of the pottery and metallurgical collections and by several structural changes in the Museum-building. The title of the new guide is "A Short Guide to the Museum of Practical Geology, Jermyn St., London, S.W." It is sold at the Museum, price one penny.

The new Geological Map Sheet 126, with the accompanying Memoir on "The Geology of the Country between Newark and Nottingham," has been illustrated by an exhibit of the minerals, rocks and fossils of the district, and by a selection of photographs.

As part of a plan for the improvement of the Collection of British Clays in the Museum of Practical Geology, samples have been obtained recently from the Cornwall and Devonshire China-Clay districts, and from the Bovey and Marland Basins in Devonshire.

Selected samples from these sources have been analysed and tested, partly with a view to the elucidation of some of the geological problems associated with the transport of the kaolinsed granites from its original position on Dartmoor to distant places; and partly in the hope that analyses together with physical tests made upon the same samples might prove of economic value.

Correlated tests of this kind made on British Clays are extremely rare.

The clays from the Bovey Basin comprise the following :—

| Museum No. | Lab. No. | |
|---|---|---|
| 730. | (301.) | A white clay (pipe clay) from a bed low down on the eastern outcrop. |
| 731. | (302.) | A white clay from the middle of the bed. |
| 732. | (303.) | A white clay from the upper part of the bed. |
| 733. | (304.) | A light body clay from the merchantable portion of a higher bed. |
| 734. | (305.) | Dark clay. |
| 735. | (306.) | Dark clay, from above No. 734, and more refractory. |

For these clays and much valuable information the Museum is indebted to Chas. D. Blake, Esq. (Messrs. Watts, Blake, Bearne & Company), Newton Abbot, Devonshire.

From the Marland Clay Works, Torrington, Devon :—

| Museum No. | Lab. No. | |
|---|---|---|
| 792. | (311.) | Potters' Blue Ball Clay. |
| 793. | (312.) | Potters' Black Ball Clay. |
| 795. | (313.) | Stoneware Clay. |

These specimens were obtained through the courtesy of H. Holwill, Esq. (North Devon China-Clay Company, Limited).

An ultimate chemical analyses was made by Dr. Pollard in the Laboratory of the Geological Survey and Museum; the results are given in Table I.

*Table I.—Complete Analyses.*

| Mus. No. | C. 730. | C.730.* | C. 731. | C. 732. | C. 733. | C. 734. | C. 735. | C. 792. | C. 793. | C. 795. | — |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ ... | 59·61 | 50·46 | 67·05 | 65·98 | 50·38 | 45·57 | 47·95 | 48·45 | 43·06 | 71·07 | $SiO_2$. |
| $TiO_2$ ... | 1·36 | 1·11 | 1·39 | 1·75 | 1·17 | ·86 | ·74 | ·84 | ·82 | 1·81 | $TiO_2$. |
| $ZrO_2$ ... | ·03 | ·02 | ·03 | ·02 | ·02 | ·03 | ·01 | ·03 | ·02 | ·04 | $ZrO_2$. |
| $Al_2O_3$... | 26·11 | 29·43 | 20·98 | 20·81 | 31·99 | 32·45 | 35·21 | 31·96 | 23·48 | 17·40 | $Al_2O_3$. |
| $Fe_2O_3$ | 1·06 | 1·71 | ·92 | 1·01 | 1·10 | 1·43 | 1·21 | 1·45 | 1·29 | ·96 | $Fe_2O_3$. |
| $Cr_2O_3$... | ·01 | tr. | ·01 | tr. | tr. | ·01 | ·01 | ·01 | ·02 | ·02 | $Cr_2O_3$. |
| $V_2O_3$ ... | ·02 | ·02 | ·02 | ·03 | ·01 | ·03 | ·01 | ·03 | ·03 | ·03 | $V_2O_3$. |
| MnO ... | ·01 | ·01 | ·01 | ·01 | ·01 | ·01 | ·01 | ·01 | ·02 | ·01 | MnO. |
| BaO ... | ·04 | ·04 | ·05 | ·05 | ·04 | ·05 | ·03 | ·06 | ·06 | ·03 | BaO. |
| CaO ... | ·30 | ·40 | ·23 | ·50 | ·41 | ·37 | ·20 | ·39 | ·48 | ·23 | CaO. |
| MgO ... | ·23 | ·24 | ·20 | ·19 | ·17 | ·14 | ·16 | ·35 | ·28 | ·16 | MgO. |
| $K_2O$ ... | 2·52 | 2·46 | 2·37 | 2·53 | 2·59 | 1·78 | 1·38 | 2·79 | 2·17 | 1·53 | $K_2O$. |
| $Na_2O$ ... | ·25 | ·45 | ·35 | ·45 | ·50 | ·30 | ·03 | ·34 | ·30 | ·17 | $Na_2O$. |
| $Li_2O$ ... | St. tr.[1] | ·03 | St. tr.[1] | ·03 | ·04 | ·03 | ·02 | ·02 | ·02 | ·02 | $Li_2O$. |
| $H_2O$ at 105° C. | 1·36 | 5·42 | ·95 | 1·19 | 2·06 | 2·77 | 1·47 | 3·25 | 4·21 | 1·43 | $H_2O$ at 105° C. |
| $H_2O$ above 105° C. | 7·11 | 8·67 | 5·36 | 5·41 | 9·31 | 12·55 | 11·81 | 10·23 | 15·33 | 5·15 | $H_2O$ above 105° C. |
| $P_2O_5$ ... | ·07 | ·08 | ·05 | ·05 | ·09 | ·08 | ·07 | ·09 | ·10 | ·07 | $P_2O_5$. |
| S ... | tr. | ·01 | tr. | ·03 | ·02 | ·21 | ·06 | ·05 | ·26 | ·04 | S. |
| $SO_3$ ... | tr. | ·08 | tr. | ·04 | ·09 | ·04 | ? tr. | nt. fd. | trace | nt. fd. | $SO_3$. |
| F ... | ·03 | ? tr. | ? tr. | ? tr. | ?? tr. | nt. fd. | nt. fd. | nt. fd. | nt. fd. | undet. | F. |
| Cl ... | ? tr. | ·01 | tr. | nt. fd. | nt. fd. | nt. fd. | nt. fd. | nt. fd. | nt. fd. | nt. fd. | Cl. |
| Organic matter. | ·29 | ·14 | ·34 | ·04 | ·01 | 1·99 | ·15 | ·30 | 3·25 | tr. | Organic matter. |
| Total ... | 100·41[2] | 100·79 | 100·31 | 100·12 | 100·01 | 100·70 | 100·53 | 100·65 | 100·20 | 100·17 | |

(1) $Li_2O$ not estimated quantitatively.
(2) Total after deducting O equivalent to F = 100·40.
* This is a sample of the clay 730 obtained from the same source at a later date.

Dr. Pollard remarks :—All the above Clays contain organic matter, though in some cases, extremely little. In consequence of this, no attempt was made to determine the state of oxidation of the iron, it has hence been given in each case as Ferric Oxide. The figures for organic matter were obtained by deducting the total water from the loss on ignition, no great reliance can therefore be placed in them.

Attention should be drawn to the combined water of No. C. 734 and 793. Owing to the presence of a fair amount of organic matter, the figures for combined water are probably too high, as in the direct estimation of the water—by heating in a combustion tube in a current of dry air and weighing the water given off—any hydrogen belonging to the organic matter would be converted into water and weighed with the true combined water of the clay. The amount of organic matter in the other specimens is hardly enough to seriously affect the combined water.

The manganese was estimated colorimetrically, probably the most accurate method for small quantities. The amount present varied in the different samples between ·006% in No. 732, to ·014% in No. 735, so these figures were rounded off to ·01 in each case.

Qualitative tests were made for carbonates, boron, and heavy metals, but none were found.

*Abbreviations used.*

| | |
|---|---|
| St. tr. ... ... | Strong trace. |
| Tr. ... ... | Trace. |
| ? tr. ... ... | Possible trace, uncertain. |
| ?? tr. ... ... | Doubtful trace. |
| Undet. ... ... | Undetermined. |
| Nt. fd. ... ... | Not found. |

Owing to the great variation in hygroscopic water, and in two cases the amount of organic matter, the above analyses have been recalculated after elimination of $H_2O$ at 105° C., $P_2O_5$, S, $SO_3$, F, Cl, and organic matter, to 100 parts.

This though not strictly accurate, is sufficiently so for purposes of comparison.

*Table II.—Recalculated Analyses.*

| Mus. No. | C. 730. | C. 730. * | C. 731. | C. 732. | C. 733. | C. 734. | C. 735. | C. 792. | C. 793. | C. 795. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ ... | 60·42 | 53·09 | 67·75 | 66·80 | 51·55 | 47·67 | 48·54 | 49·97 | 46·62 | 72·06 | $SiO_2$. |
| $(TiZr)O_2$ | 1·41 | 1·19 | 1·43 | 1·79 | 1·22 | ·93 | ·76 | ·90 | ·91 | 1·86 | $(TiZr)O_2$. |
| $Al_2O_3$ ... | 26·47 | 30·97 | 21·20 | 21·07 | 32·73 | 33·94 | 35·65 | 32·96 | 30·83 | 17·64 | $Al_2O_3$. |
| $(FeCrV)_2O_3$ | 1·10 | 1·82 | 0·96 | 1·05 | 1·13 | 1·54 | 1·24 | 1 54 | 1·45 | 1·02 | $(FeCrV)_2O_3$ |
| MnO ... | 0·01 | 0·01 | 0·01 | 0·01 | 0·01 | 0·01 | 0·01 | ·01 | ·02 | ·01 | MnO. |
| (BaCa) O | 0·34 | 0·46 | 0·28 | 0·56 | 0·46 | 0·44 | 0·23 | ·46 | ·58 | ·26 | (BaCa) O. |
| MgO ... | 0·23 | 0·25 | 0·20 | 0·19 | 0·17 | 0·14 | 0·16 | ·36 | ·30 | ·16 | MgO. |
| $(KNaLi)_2O$. | 2·81 | 3·09 | 2·75 | 3·05 | 3·20 | 2·21 | 1·45 | 3·25 | 2·69 | 1·75 | $(KNaLi)_2O$. |
| $H_2O$ above 105°C. | 7·21 | 9·12 | 5·42 | 5·48 | 9·53 | 13·12 | 11·96 | 10·55 | 16·60 | 5·22 | $H_2O$ above 105° C. |
| Total ... | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100 00 | |

* This is a sample of the clay 730 obtained from the same source at a later date.

A "rational" or "proximate" analysis of Nos. 730, 731, 732, 733, 734, 735, and 795 was subsequently undertaken by Mr. Walter C. Hancock, B.A., F.I.C., under the direction of the Curator.

These were carried out according to Lunge's process; the results are stated below :—

*Table III.—Rational Analysis.*

| Museum Number, | 730 | 731 | 732 | 733 | 734 | 735 | 795 |
|---|---|---|---|---|---|---|---|
| "Clay Substance"... | 84·47 | 56·76 | 57·70 | 71·86 | 88·75 | 83·28 | 57·40 |
| "Quartz" ... ... | 14·71 | 41·90 | 40·44 | 24·73 | 10·50 | 15·16 | 41·11 |
| "Felspar"... ... | ·82 | 1·34 | 1·86 | 3·41 | ·75 | 1·56 | 1 49 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

The physical properties of the clays, except Nos. 792 and 793, have been investigated by Mr. Hancock.

The series comprised tests on :—

(*a.*) *On the raw clay.*—The specific gravity, plasticity, shrinkage on drying, tensile strength and texture were determined.

(*b*) *On the burnt clay.*—The specific gravity, shrinkage on burning, tensile strength, porosity and fusing point were determined.

Plasticity was measured by the Vicat needle; the "Plasticity Number" in the table is obtained from the formula :—

$$\frac{\text{Weight of water}}{\text{Weight of dry clay}} \times 100.$$

It should be noticed that the "Clay Substance" in the physical tests, Table IV., connotes fine-grained material.

For the determination of the Texture results, Schoene's eleutriating apparatus was used.

The discussion of the results obtained in these analyses and tests, and remarks upon the methods employed, are deferred until the examination of this series of clays is completed.

*Table IV.—Physical Tests on the Raw Clay.*

| Museum Number. | | 730 | 731 | 732 | 733 | 734 | 735 | 795 |
|---|---|---|---|---|---|---|---|---|
| Specific gravity at 15·5°C. ... | | 2·69 | 2·66 | 2·71 | 2·68 | 2·58 | 2·62 | 2·68 |
| Plasticity number ... ... | | 32·5 | 21·2 | 20·5 | 35·2 | 38·7 | 37·7 | 26·0 |
| Shrinkage on drying, per cent. | | 5·0 | 3·5 | 3·6 | 4·1 | 4·9 | 4·8 | 4·3 |
| Tensile strength, lbs. per sq. in. | | 40 | 41 | 58 | 37·5 | — | 5·0 | 73 |
| Texture | Clay substance ... | 57·45 | 78·47 | 56·11 | 29·30 | 74·35 | 35·33 | 69·43 |
| | Silt ... ... | 2·13 | 4·93 | 6·86 | 27·00 | 6·29 | 6·47 | 11·49 |
| | Dust sand ... | 9·46 | 12·20 | 20·10 | 10·38 | 7·61 | 8·87 | 9·85 |
| | Sand ... ... | 30·96 | 4·38 | 16·93 | 33·32 | 11·75 | 49·33 | 9·23 |

*Table V.—Physical Tests on the Burnt Clay.*

| Museum Number. | 730 | 731 | 732 | 733 | 734 | 735 | 795 |
|---|---|---|---|---|---|---|---|
| Sp. Gr., burnt at 1200°C. | 2·56 | 2·52 | 2·56 | 2·56 | 2·62 | 2·65 | 2·62 |
| Shrinkage, burnt at 600°C. | 5·3 | 3·5 | 3·5 | 4·1 | 5·2 | 4·8 | 500°—4·3 |
| „ „ 900°C. | 6·0 | 3·7 | 3·7 | 4·1 | 5·4 | 5·0 | 800°—4·3 |
| „ „ 1200°C. | 6·9 | 4·4 | 4·1 | 7·6 | 7·5 | 7·6 | 1000°—4·5 |
| | | | | | | | 1200°—5·6 |
| „ „ 1300°C. | 11·8 | 11·0 | 9·0 | 14·1 | 8·4 | 9·1 | 1300°—8·3 |
| Tensile strength, burnt at 1200°C. | 665 | 90? | 688 | 136 | 165 | 160 | 240 |
| Porosity, burnt at 1200°C. | 19·7 | 13·9 | 14·7 | 11·0 | 20·1 | 23·8 | 6·7 |
| Fusing points, Seger Cones. | 26–27 | 26–27 | 27 | 28 | 26–27 | 28 | 26 |
| Fusing points, degrees Centigrade. | 1595° | 1595° | 1610° | 1630° | 1595° | 1630° | 1580° |

LIST OF DONATIONS DURING THE YEAR 1909

AKEROYD AND SONS, LTD., MESSRS.—The following samples of Building Stones, viz. (Sandstones), "Hard Excelsior Blue," "Dark Derbyshire," "Light Derbyshire," and "Hard Finsdale Brown."

ANDERSON, T. C. H., ESQ.—Samples of Kaolin from Eyzies, France.

ANSILL, MISS M.—Specimen of Beekite from the Livermead Rocks, Torquay, Devonshire.

ARMITAGE AND SONS, LTD., MESSRS. GEORGE.—The following samples of Building Stones, viz.—"Ackworth," "Armistone," "Bradford," "Bramley Fall," "Bolton Wood," "Corsehill," "Cullingford," "Eccleshill," "Howley Park," "Huddlestone," "Park Nook," "Park Spring," "Red Mansfield" and "Robinhood."

ASHMORE, G. P., ESQ.—Two samples of the diamond-bearing sand from the Dunes, Luderitzbucht Diamond Fields, German South-West Africa.

BAKER, LADY.—Bowl and Stand of Ceramic Marble.

BARING-GOULD, MISS S.—Specimens of Hellandite from Kragerö, Norway.

BARROW, G., ESQ., F.G.S.—Ten specimens and corresponding slides of Cornish Rocks.

BRISTOW BROS., MESSRS. T.—One large and one small block of Denner Hill "Sarsen" Stone.

BRITISH METALLIFEROUS MINES, LTD., MESSRS. THE.—Pitchblende, from the Uranium Mine, Grampound Road, Cornwall.

BROWN, MISS BOYER.—Beekite, from the Livermead Rocks, Torquay, Devonshire.

CARUS-WILSON, CECIL, ESQ., F.G.S.—Root of Oak showing the natural inclusion of stones in woody tissue.

CLOUGH, C. T., ESQ., M.A., F.G.S.—Two Specimens of "Eenie" Coal from Gateside Colliery, Cambuslang, Lanarkshire.

DENNIS & CO., MESSRS.—Three samples of "Cefn" stone.

EASTLAKE, A. W., ESQ., M.Inst.M.E.—Gypsum Crystals formed in the Sands of Karatchungul Lake, Guriew District, Uralsk Province, Caspian Sea.

EDEN, REV. A. (per H. B. WOODWARD, ESQ.).—A polished specimen of Boulder, Peppercombe Bay, N. Devon.

FARMER AND BRINDLEY, MESSRS.—Specimen of Sodalite showing the effect of heat in decolorising the mineral.

LETT, J. S., Esq., M.A., D.Sc., F.G.S.—*Osteolepis macrolepidotus* Ag., *Microbrachium dicki* Traq., *Dipterus macropterus* Traq., from the Old Red Sandstone of Orkney.

'ORD, C., Esq.—*Cliona cretacea* (Portl.) from the gravel of Walton-on-the-Hill.

'OREST OF DEAN STONE FIRMS, LTD., MESSRS. THE.—Samples of "Blue Bristol Pennant," "Pink Bristol Pennant" from Huckford Quarry, Winterbourne; also "Red Wilderness," "Shamrock," "Nailsworth," "Mount Charles," "Grey Forest of Dean" (Coffee Pit), and "Blue Forest of Dean" (Oak Quarry).

'OX, H., Esq., F.G.S.—Fossils from the Upper Devonian of Trevone, Cornwall.

'LENBOIG FIRE CLAY CO., MESSRS. THE.—One specimen of Fire Clay, Glenboig, Lanarkshire.

[ERON-ALLEN, E., Esq.—Pseudomorphous Limonite in the interior of a flint; four crystals of Selenite from Drainage Works, West Barnes Lane.

[ITCHIN, MARTIN T., Esq.—A series of China Stone, China Clay, and associated minerals.

[OLMES, T., Esq.—Crystallised Malachite from Scouts Quarry, Carnforth, Lancashire.

[OWLEY PARK AND GREAT FINSDALE QUARRY CO., LTD., MESSRS. THE.—Samples of "Green Woodkirk," "Howley Park Brown," and "Hard Woodkirk Blue" stones.

[UGHES, H. W., Esq., A.R.S.M., F.G.S.—*Pygocephalus cooperi* Hux., from the Coal Measures of Coseley, near Dudley.

OHNSTON, MISS M. S.—Geyser Pipe from Lake Roto-Kawa, New Zealand.

ONES, O. T., Esq., M.A., B.Sc.—*Monograptus atavus*, *Monograptus rheidolensis*, figured and described by the donor; *Quart. Journ., Geol. Soc.*, LXV., pp. 531–535. *Mesograptus modestus* Lapw., *Mesograptus modestus* var. *parvulus* H. Lapw., *Mesograptus magnus* H. Lapw., figured and described in the Palæontographical Society's volume for 1907, pp. 263, 264, 266.

UKES-BROWNE, A. J., Esq., B.A., F.R.S.—*Heliolites porosus* (Goldf.) from the Middle Devonian of Hele, Torquay, Devonshire.

YLE, J. A. J., Esq.—Serpentine from the Barberton District, Transvaal; Auriferous Pyrite from Cwm Prysor, Merioneth; Auriferous Sand from de Kaapp River, Barberton, Transvaal.

ATHAM, BALDWIN, Esq., M.Inst.C.E., F.G.S.—*Plectambonites* and *Atrypa* from a well at Cliffe, Kent.

EVY AND NEPHEWS, MESSRS.—Glass models of nine brilliants cut from the "Cullinan" Diamond.

ONDON GRANITE CO., LTD., MESSRS. THE (per H. L. WETTERN, Esq.).—Box of Samples of "Quenast" Stone.

[AYOR, MARCUS, Esq.—Specimens of Copal Gum from the Congo, Brazil, Manilla, and from Auckland, New Zealand.

[OYSEY, Dr. L., F.G.S.—*Palæoxyris helicteroides* (Morris) from the Coal Measures of Digby Clay Pit, Kimberley, Nottinghamshire.

[URRAY AND SONS, MESSRS. J.—Two samples of "Corsehill" Stone.

'ORTH AND ROSE, MESSRS.—Several specimens of China Stone.

AKELEY SLATE QUARRIES CO., LTD., MESSRS. THE.—Fifteen samples of Slate from the Oakeley Quarries, North Wales. (5 qualities.)

'DRISCOLL, F., Esq.—Two specimens of Umangite from Puesto de la Angostura Mine, near Piedra Pintada, Rioja, Argentine, South America.

ETER, C. H., Esq.—*Proetus dunhevidensis* I. Thomas, from the Upper Devonian of South Petherton.

OTTER, GEO., Esq.—A series of specimens from the Drift of Finchley.

UEENSLAND COMMISSIONER AT FRANCO-BRITISH EXHIBITION.—Large specimen of Molybdenite with Quartz, and specimen of Chromite, from Queensland.

RAIKES, T., ESQ.—Sample of Building Stone from Bwlch Quarry, Brecknockshire.

READ, CURWEN, ESQ.—Five specimens of Auriferous Quartz from Zapucay, Dept. of Rivera, Uruguay; Manganese Ore from a lode south of Zapucay; Bornite and Chalcopyrite from Comaqua, State of Rio Grande del Sud, Brazil; specimens showing the occurrence of Lignite with Arsenopyrite, and a sample of the overlying sandstone, Rio Negro, State of Rio Grande del Sud, Brazil.

REYNOLDS, PROF. S. H.—Fifteen Arran Rocks; forty-five miscellaneous Foreign Rocks; fifteen Rocks, Bartestree Dyke and associated rocks; twenty-five rocks from the Dolgelly area.

RUSSELL, A., ESQ.—Limonite, iridescent, from Ballymurtagh Mine, Vale of Ovoca, Co. Wicklow; Dolomite from Chuley Quarry, Ashburton, Devonshire; Asbestos, from Gimlet Rock Quarry, Pwllheli, Carnarvonshire; fifteen Museum specimens of Donegal rocks.

SOUTH-EASTERN DEVELOPMENT SYNDICATE, LTD., MESSRS. THE.—Gypsum from boring near Battle, Sussex.

THOMPSON, J. ALLEN, ESQ.—Three Dunedin Rocks, New Zealand.

WALKER & CO., LTD., MESSRS. G. H.—A series of rocks from the Transandine Tunnel, Cumbrie.

WETTERN, H. L., ESQ.—A block of "Grey Royal" granite.

WILLS & CO., MESSRS. GEO.—A series of specimens of Gold Ores, Lead Ores, Copper Ores, Asbestos, Mica and Garnets, from Arltunga and Winnecke, Southern Australia.

WOODWARD, H. B., ESQ., F.R.S.—Floating Pebbles from East Africa; two Flint Flakes from loam beneath the Boulder Clay, Mildenhall; two Flint Flakes found *in situ*, Stone Bed, Norwich Crag, Thorpe, near Norwich: Flint Flake, Norwich Crag, Whittingham; Flint Flake, Boulder Clay, north of Lowestoft; seven Museum specimens of miscellaneous rocks from England and Scotland.

—— *Otodus obliqus* Ag. from the London Clay of Claygate, Esher.

YORKSHIRE SILICA FIRE BRICK CO., MESSRS. THE.—Three samples of Stone from the "Beeley Wood," "Hawksworth" and "Idle" Quarries, Yorkshire.

# VI.—MAPS, MEMOIRS, AND SECTIONS PREPARED AND PUBLISHED.

The following is a list of the Maps, Memoirs and Sections issued by the Geological Survey during the past year :—

## A. ENGLAND AND WALES.

### I.—MAPS.

#### (*a*) *Four Miles to One-inch.*

New Series. Solid Edition.

Sheet 12 (Louth, Peterborough, Norwich, and Yarmouth), price 2s. 6d.
Sheet 16 (Cambridge, Colchester, Ipswich, &c.), price 2s. 6d.
Sheet 20 with 24 (London, Dover, and Brighton), price 2s. 6d.
Sheet 21 with 25. (Bodmin, Truro, Falmouth, Land's End, Isles of Scilly), price 2s. 6d.

#### (*b*) *One-inch Maps* (*New Series*).

(Colour-printed, price 1s. 6d. each.)

Sheet 142, Melton Mowbray (Drift).
Sheet 347, Bodmin (Drift).

A colour-printed Drift Edition of the following New Series Sheets has been issued, and replaces the Old Series hand-coloured Drift Edition. Old Series numbers given in square brackets :—34 [104 S.W.], 35 with 44 [104 S.E. and 95 N.W.], 43 [96 N.E.], 53 [96 S.E.], 55 [95 S.E.], 63 [93 N.E.], 64 [94 N.W.], 65 [94 N.E.], 71 [93 S.E.], 72 [94 S.W.], 73 [94 S.E.].

#### (*c*) *Six-inch Maps of Mining Districts.*

The undermentioned six-inch maps have been published with geological information (uncoloured, price 1s. 6d. each): coloured copies can also be obtained at an additional charge for colouring :—

Carmarthenshire.—41 S.E. ; 47 N.W., N.E., S.W., S.E. ; 48 N.W., N.E., S.W., S.E. (Glam., 1 S.E.) ; 53 N.E., S.E. ; 54 N.W., N.E.
Glamorganshire.—7 N.W. (Carm. 55 N.W.).

#### (*d*) *Six-inch Reference Maps.*

Two hundred and ten MS. coloured copies of six-inch sheets have been made from the field-copies, and deposited in the Office for Public Reference. They are as follows :—

Carmarthenshire.—36 S.W. ; 37 N.E., S.W., S.E. ; 44 N.W.
Cornwall.—10 N.W., N.E., S.W., S.E. ; 11 S.W. ; (13 N.E. and 14 N.W), 13 S.E., ; 14 N.E., S.W., S.E. ; 15 N.W., S.W., S.E. ; 17 S.W. ; 18 N.W., (13*a* S.E. and 18 N.E.), 18 S.W., S.E. ; 18*a* S.E. ; (13 S.W. and 19 N.W.) ; 19 N.E., S.W., S.E. ; 20 N.W., N.E., S.W., S.E. ; 21 N.W., N.E., S.W., S.E. ; 22 S.W. ; 23 N.W., N.E. ; 24 N.W., N.E. ; 25 N.W., N.E., S.E. ; 26 N.W., N.E., S.W. : 27 N.E., S.E. ; 28 N.W., N.E., S.W., S.E. ; 29 N.W., N.E., S.W., S.E.

Derbyshire.—25 N.W., N.E., S.E. ; 26 N.W., S.W. ; 29 S.W. ; 30 N.E., S.E. ; 31 N.W. (Notts. 22 N.W.), 31 S.W. (Notts. 22 S.W.) ; 31 S.E. (Notts. 22 S.E.) ; 34 N.W., S.W., S.E. ; 35 N.E., S.W., S.E. ; 36 N.W. (Notts. 27 N.W.), 36 S.W. (Notts. 27 S.W.), 39 S.E. ; 44 N.E., S.E.

Devonshire.—97 N.E. ; 99 N.W., N.E., S.W., S.E.

Durham.—58 N.W.

Flintshire.—1 S.E. ; 2 N.W., S.W. (part) ; 4 N.E. (part) ; 5 N.W., N.E. (part), S.E. ; 8 N.W., N.E., S.W., S.E. ; 12 N.E. ; 13 S.W., S.E. (part) ; 16 N.E. (part), S.E. ; 17 N.W., S.W. (part).

Leicestershire.—13 N.W., N.E., S.W., S.E. ; 20 N.W., N.E., S.W., S.E. (Rutland, 1 S.E.).

Northumberland.—33 S.E. ; 34 N.E., S.W., S.E. ; 35 N,W., N.E , S.W., S.E. ; 36 N.W., N.E., S.W , S E. ; 43 N.W., N.E., S.W., S.E. ; 48 N.E., S.E. ; 49 N.W., N.E., S.W., S.E. ; 50 N.W., N.E., S.W., S.E. ; 51 N.W., N.E., S.W., S.E. ; 52 N.W., N.E., S.W., S.E. ; 57 N.E., S.E. ; 58 N.W., N.E., S.W., S.E. ; 59 N.W., N.E., S.W., S E. ; 60 N.W., N.E., S.W., S.E. ; 61 N.W., N.E , S.W., S.E. ; 62 N.W., N E., S.W., S.E.

Nottinghamshire.—18 N.E., S.E. ; 21 N.W. (part), 21 S.W. (part) ; 24 N.E., S.E. ; 25 N.W., N.E., S.W., S.E. ; 26 N.W. (part), 26 S.W. (part) ; 27 S.E. ; 34 N.W., N.E., S.W., S.E.

Pembrokeshire.—23 S.E. ; 24 S.W. ; 27 N.E. ; 28 N.W. ; 29 N.E.

M.S. copies of the following maps showing the Solid Geology have been deposited in the Office for Public Reference. The Drift editions of these sheets are published.

Derbyshire.—58 S.W. (Leic., 9 S.W.) ; 60 N.W. (Staffs, 47*a* N.W.), 60 S.W. (Leic. 15 S.W.) ; 63 N.E. (Leic. 22 N.E.).

Leicestershire. —16 S.W. ; 22 S.E. ; 23 N.W., S.W., S.E.

Staffordshire.—3 S.W., S.E. ; 6 N.E., S.W. ; 7 N.W. ; 11 N.W., N.E., S.W. ; 16 N.E., S.E. ; 17 N.E., S.W.

## II.—MEMOIRS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1908, pp. 98. Price 1*s.*

Geology of the London District. Being the area included in Sheets 1–4 of the Special Map of London, by H. B. Woodward, F.R.S. pp. 142. Price 1*s.*

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# APPENDIX I.

## On a boring at Stowell, Somerset.*

By John Pringle.

In an appendix to the Summary of Progress for the year 1908, I gave an account of a boring in Fullonian and Inferior Oolite rocks at Stowell, near Templecombe. Since that time further boring has been undertaken, and again through the courtesy of Mr. W. Phelps, C.E., I was allowed to examine and break up the cores. I am also greatly indebted to Mr. A. W. Moore, the engineer in charge of the boring, for supplying me with a copy of his journal by means of which I was enabled to note accurately the depth of each bed.

The boring, which had for its object the obtaining of a water supply for Templecombe, was unsuccessful, and the only water met with was an insufficient quantity derived from the Fullers Earth Rock.†

The following is a description of the strata between the depths of 350 feet to 553 feet.

| | ft. | ft. |
|---|---|---|
| Hard grey limestone, with thick marly beds ... ... | 70 | 420 |
| Light grey limestone, with numerous dark shaly bands ... | 28 | 448 |
| Cream coloured limestone ... ... ... ... ... | 2 | 450 |
| Dark grey limestone ... ... ... ... ... ... | 5 | 455 |
| Soft dark greenish-grey sands, with alternations of thin shelly limestones; the limestones becoming more sandy and less calcareous below ... ... ... ... ... | 98 | 553 |
| The Inferior Oolite passes down into Bridport Sands at about 450 feet, and Yeovil Sands at about 500 feet. | | |

In the above section, the beds from 455 feet to 553 feet are a repetition of thin grey limestones and soft greenish-grey sands, and, as will be seen from the correlation table, the upper part of these nearly coincides with the top of the Bridport Sands of the Bridport district. Near the top the limestones are shelly, being largely composed of the comminuted fragments of lamellibranchs, but below they become more sandy and impure. This has been noted on the outcrop of these beds. Mr. H. B. Woodward‡ remarks that "at Yeovil Junction by the London and South Western Railway Station, a cutting on the Great Western Railway, and also in the loop line to the east, the Sand contains here and there beds of hard shelly limestone composed chiefly of comminuted shells in addition to the ordinary bands and scattered nodules of sandy limestone or calcareous sandstone," and he further states§ that "the chief interest attaching to these limestones, of which 3 or 4 bands may sometimes be found, is that they indicate the change which further on at Ham Hill is marked by the celebrated building stone of that locality."

---

* *See also* 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, pp. 83–86.

† The yield of water from the Fullers Earth Rock was proved to be 25,000 gallons per day.

‡ 'The Jurassic Rocks of Britain,' vol. iv. (*Mem. Geol. Surv.*), 1894, p. 74.

§ *Ibid.*, pp. 74 and 75.

Excepting the shelly limestones, the sands appeared to be very unfossiliferous, but that may be due to the fact that the cores had lain exposed for several months.

The following is a list of the fossils collected from the cores, with the depths from which the specimens were obtained. All the brachiopods and cephalopods were submitted to Mr. S. S. Buckman for determination; the remainder of the fossils, except *Trigonia navis*, have been identified by myself.

| | Depths. |
|---|---|
| Serpula sp. ... ... ... ... ... ... ... | 461′ 9″–462′ 3″ |
| Acanthothyris obornensis *S. Buckm. & Walker* ... ... | 406′–410′ |
| „ paucispina *S. Buckm. & Walker* ... ... | 416′ |
| Rhynchonella ringens (*von Buch*) ... ... ... ... | 445′–448′ |
| „ sp. nov. [of the "*ringens*" group, but broader, and with quite a different fold] ... ... | „ |
| Terebratula ferryi *Dav.* [non Deslongchamps = Dav., App. to Suppl., pl. xviii., figs. 20 & 21] ... ... ... | 388′–390′ |
| Terebratula hollandæ *S. Buckm.* ... ... ... ... | 365′–367′ |
| „ sp. [= T. decipiens *Dav.* pars, = elongate form of T. sphaeroidalis *Auctt.*] ... ... ... | 406′–410′ |
| Terebratula sp. [= flat form of T. sphaeroidalis *S. Buckm.*, Q.J.G.S., 1893, Vol. xlix., p. 496] ... ... ... | 388′–390′ |
| Terebratula sp. ... ... ... ... ... ... | 365′–367′ |
| *Cf.* Cyprina nuciformis *Lyc.* ... ... ... ... | 406′–410′ |
| Grammatodon oblongus (*J. de C. Sow.*) ... ... ... | 445′–448′ |
| Gresslya? ... ... ... ... ... ... ... | 416′ |
| Lima (Plagiostoma) sp. ... ... ... ... ... | 445′–448′ |
| Lucina sp. ... ... ... ... ... ... ... | 365′–367′ |
| Ostrea sp. ... ... ... ... ... ... ... | 478′–478′ 6″ |
| Pecten (Chlamys) *cf.* articulatus *Goldf.* [? *Schloth.*] ... | 445′–448′ |
| „ (Syncyclonema) demissus *Phill.* ... ... ... | 365′–507′ |
| „ *cf.* laeviradiatus *Waagen* ... ... ... ... | 445′–481′ 9″ |
| Placunopsis jurensis (*Roem.*) ... ... ... ... | 445′–448′ |
| Pleuromya sp. ... ... ... ... ... ... ... | 416′–448′ |
| Plicatula sp. ... ... ... ... ... ... ... | 445′–448′ |
| Pseudomonotis *cf.* echinatus (*J. Sow.*) ... ... ... | 459′–462′ 3″ |
| Pteria (Oxytoma) costata (*J. Sow.*) ... ... ... | 365′–481′ 9′ |
| „ „ inequivalvis (*J. Sow.*) [sensu lato] ... | 365′–367′ |
| Tancredia? .. ... ... ... ... ... ... | 459′ |
| Trigonia costata *J. Sow.* ... ... ... ... ... | 463′ |
| „ navis *Lam.* ... ... ... ... ... | 480′ 6″–481′ 9′ |
| „ *cf.* striata *J. Sow.* ... ... ... ... ... | 459′ |
| Unicardium? ... ... ... ... ... ... ... | 365′–367′ |
| Pleurotomaria sp. ... ... ... ... ... ... | 354′–416′ |
| Cotteswaldia limatula? *S. Buckm.* ... ... ... ... | 450′–455′ |
| ? „ sp. [allied to C. distans *S. Buckm.*] ... ... | 480′ 6″–481′ 9″ |
| Dumortieria rustica *S. Buckm.* ... ... ... ... | 507′ |
| Ludwigella nodata *S. Buckm.* ... ... ... ... | 445′–448′ |
| „ sp. [? *Cf.* L. attenuata *S. Buckm.*] ... ... | „ |
| Nautilus sp. ... ... ... ... ... ... ... | 365′–367′ |
| Parkinsonia *aff.* rarecostata *S. Buckm.* ... ... ... | 354′–356′ |
| Pleydellia subcompta (*S. Buckm.*) [? (*Branco*)] ... ... | 450′–455′ |
| „ sp. [between P. aalensis (*Zieten*) and P. fluens *S. Buckm.*] ... ... ... ... ... ... | „ |
| Sonninia *aff.* buckmani *Haug* ... ... .. ... | 416′ |
| „ sp. nov. ... ... ... ... ... ... | „ |
| *Cf.* Walkeria burtonensis *S. Buckm.* ... ... ... | 450′–455′ |
| Belemnites sp. ... ... ... ... ... ... ... | 416′–448′ |

With regard to the specimen which is entered in the above list as *Trigonia navis* Lam., this identification was first suggested by Mr. S. S. Buckman. The specimen is poorly preserved, and little of the original shell remains, but the principal characters are

sufficiently well shown. The ornaments of the flat anterior face are greatly obscured by intractible matrix, but traces of the thickened tubercular terminations of the horizontal frontal ribs can be seen. Dr. Kitchin has made a careful comparison with Swabian examples of the species in his possession, and he is convinced that the specimen should be referred definitely to *T. navis*. This occurrence is of interest since this well-known species appears not to have been previously recorded from any locality in Great Britain. *T. navis* occurs most commonly in continental localities where there is an argillaceous development in the base of the Inferior Oolite Series.

By means of the brachiopods and cephalopods, Mr. Buckman has kindly drawn up the following table of zones and their correlations :—

| Depth. | Zones. | | Correlation. |
|---|---|---|---|
| 354 ft.–356 ft. | Garantiana Zone, part. | upper | = Lower part of Rubbly Beds of Sherborne ; Astarte Bed of Burton Bradstock. |
| 388 ft.–410 ft. | Garantiana Zone, part. | lower | = Building Stone of Sherborne, Oborne, &c. |
| | (1) | | |
| 416 ft. ... | Sauzei Zone | | = Marl with green grains, Frogden Quarry, Oborne. |
| | (2) | | |
| 445 ft.–448 ft. | Bradfordensis Zone | | = *Rhynchonella ringens* Beds of Corton Denham. |
| | (3) | | |
| 450 ft.–455 ft. | Aalensis Zone | | = Top part of Bridport Sands of Bridport district. |
| 480 ft.–481 ft. | Aalensis or Moorei Zone. | | |
| 507 ft. ... | Moorei Zone | | = About top part of Yeovil Sands of Yeovil district. |

(1) Niortensis and Blagdeni Zones wanting ?
(2) Discites and Concava Zones wanting ?
(3) Murchisonæ-Opaliuiformis Zones wanting ?

# APPENDIX II.

## Notes on Three Borings in the Ingleton Coalfield, by W. Gibson, D.Sc.

We are indebted to Mr. W. Fairclough for permission to publish the following notes on three borings, completed between 1904–06, in the Ingleton Coalfield. No. 1 boring, near High Bentham Station, and No. 2, 260 yards south-east of Seat Hall, are on the south-west side of the coalfield; No. 3 boring, 350 yards north of Moorgarth Hall, is toward the east side.

At No. 3 the section proved consists of: (1) Drift, 129 ft. 6 ins.; (2) red marl and sandy marl, 358 ft.; (3) red sandstone, 27 ft.; (4) red and grey marls, mixed, 236 ft.; (5) ordinary grey Coal Measures with coal-seams, 607 ft. These thicknesses must be corrected for a dip of 10 degrees in the case of (2), (3), and (4), and for a slightly higher dip in (5). The fossils in the grey Coal Measures consist of *Carbonicola acuta* at 922 ft. depth, and a small *Lingula* in a shale band, 1 ft. 6 ins. thick at 928 ft., with a few fragmentary plant-remains at several horizons. The gradual passage of the grey measures into the essentially red-marl series suggests that the latter are of Coal Measure age, and this is confirmed by the presence of *Neuropteris*, *Lepidodendron*, and *Sigillaria*, distributed practically throughout the red strata. The plants, however, are not sufficiently well preserved to determine the exact position in the Coal Measure sequence.

An abstract of the record of No. 2 boring gives: (1) Drift, 37 ft.; (2) black, fossiliferous, sandy shales, 108 ft.; (3) coarse grit, with a shale-band (42 ft. thick), 291 ft.; (4) dark-grey, fossiliferous shales, 101 ft.; coarse grey sandstone, 64 ft. Total depth of boring, 601 ft. 4 ins.

In No. 1 boring the section is: (1) Drift, 38 ft.; (2) coarse grey sandstone, 56 ft.; (3) a grit-and-shale series down to the bottom of the boring at 602 ft.

Owing to the thick cover of Drift, it is not possible to assign an exact position of the two latter borings in the Carboniferous sequence. No 2 commences either in the basal beds of the Lower Coal Measures, or else in the shales below the highest Millstone Grit. No. 1 boring is entirely in Millstone Grit, and possibly commences where No. 2 boring ended.

With the exception of the barren shales in No. 2 boring, and of a band (447–493 ft. depth) in No. 1, the shales are extremely fossiliferous, all the fossils being of a marine character, as shown in the following list:—

| | No. 1. | No. 2. |
|---|---|---|
| Crinoidal columnals ... ... ... ... ... | C, D, E, F | — |
| Chonetes laguessiana *de Kon* ... ... ... ... | F | B |
| Lingula mytiloides *J. Sow.* ... ... ... ... | E, F | A, B |
| Orbiculoidea nitida (*Phill.*) ... ... ... ... | C, F | A, B |
| Productus sp. [semireticulate form] ... ... ... | C, D, F | A, B |
| ? Rhipidomella michelini (*Léveillé*) ... ... ... | C | — |
| *Cf.* Spirifer bisulcatus *J. de C. Sow.* ... ... ... | — | B |
| *Cf.* Grammatodon meridionalis (*de Kon.*) [? new] ... | — | A |
| *Cf.* Nucula oblonga *McCoy* [? new] ... ... ... | — | A |
| Nuculana *cf.* attenuata (*Flem.*) ... ... ... ... | E | — |

| | No. 1. | No. 2. |
|---|---|---|
| Posidoniella sulcata *Hind.* ... ... ... ... | — | B |
| Pterinopecten papyraceus (*J. Sow.*) ... ... ... | — | B |
| Solenomorpha? [? new] ... ... ... ... ... | — | A |
| Mourlonia? [probably new] ... ... ... ... | E | — |
| Euphemus *cf.* urei (*Flem.*) ... ... ... ... | E | — |
| Coloceras? ... ... ... ... ... ... ... | E | — |
| Glyphioceras reticulatum (*Phill.*) ... ... ... | — | B |
| „ *cf.* reticulatum ... ... ... ... | — | A |
| „ sp. ... ... ... ... ... ... | D, E | — |
| Orthoceras? ... ... ... ... ... ... | C | A, B |

EXPLANATION of LETTERS in columns 1 and 2.—A, between 37–145 feet depth, B, 436–537 feet, C, 94–214 feet, D, 233–318 feet, E, 330–377 feet, F, 546–602.

The specimens, which are in the collection of the Geological Survey, have been named by Dr. Ivor Thomas.

It is interesting to note that the fossils, with the exception of the new forms *Solenomorpha*, *Mourlonia*, and *Grammatodon*, are common to the shales between the Carboniferous Limestone and Millstone Grits in Yorkshire, North Staffordshire and Lancashire, and are also equally abundant in the marine beds high up in the Middle Coal Measures of these coalfields. This extensive vertical distribution of a marine, and in part a specialised, fauna indicates either that the type was unusually persistent, or that the deposition of the Upper Carboniferous sediments was unusually rapid.

# APPENDIX III.

## On a Manganese Deposit near Freswick, Caithness.

*Mode of Occurrence.*

By C. B. Crampton, M.B., C.M.

The manganese deposit of which the analysis is given in the sequel is formed in considerable quantity as a blue-black mud where a spring issues in the peat bog near Freswick. The spring is a source of one of the small feeders of the Burn of Bog which is a northern branch of the Gills Burn at the Bridge of Freswick. It is situated about 100 yards from the main stream and at a distance of about 1660 yards in a north-west direction from the Bridge.

The water of the spring is clear and smells strongly of sulphuretted hydrogen. The spring has long been known to the local geologists as a source of sulphuretted hydrogen and manganese mud.

*Analyses.*

By W. Pollard, M.A., D.Sc., F.I.C. and E. G. Radley.

| | | |
|---|---|---|
| $SiO_2$ | ·33 | |
| $(FeAl)_2O_3$ | ·23 | |
| MnO | 56·07 | |
| (CoNi)O | ·10 | |
| BaO | 1·26 | |
| CaO | ·70 | |
| MgO | ·15 | |
| $K_2O$ | ·33 | |
| $Na_2O$ | ·13 | |
| $P_2O_5$ | ·05 | |
| $SO_3$ | ·16 | |
| Loss on ignition | 36·55 | |
| Peroxide O equivalent to MnO (I.E. in ratio $3MnO : O = Mn_3O_4$ Calc.) | 4·21 | (Found by direct estimation in residue from loss on ignition, by oxalate method 4·30.) |
| | 100·27 | |

Total peroxide oxygen found by oxalate method 10·09.

If all the manganese were present as $MnO_2$ 12·74 per cent. O would be required. The ratio of Mn : O is ·7897 : 1·4206 or about 1 : 1·8 which gives 7 $MnO_2$, $Mn_3O_4$.

The composition of the matter driven off on ignition is :—

| | |
|---|---|
| Peroxide oxygen (10·09–4·21) | 5·88. |
| $CO_2$ (present as carbonate) | ·17. |
| $H_2O$ at 105°C. | 19·55. |
| $H_2O$ above 105°C. | 6·62 (or 6·83) (Mean 6·72). |
| Organic matter | 4·15 (or 3·83) (Mean 3·99). |

It will be noticed that the sum of the constituents, 36·37 (or 36·26) approximates very closely to the value obtained by direct estimation, viz., 36·55.

The results tabulated above were obtained as follows :—

*Peroxide Oxygen.*—This was estimated by dissolving in excess of either ferrous ammonium sulphate, or oxalic acid, in presence of dilute sulphuric acid and titrating back with permanganate. These two methods gave concordant results, so if the organic matter interfered at all, the interference was equal in each ca[illegible]

The chlorine method was also tried but, although duplicate determinations agreed fairly well together, the results were ·5 per cent. lower than those obtained by the ferrous sulphate or oxalic acid methods. The low results got by the chlorine method are, no doubt, due to the partial oxidation of the organic matter by the nascent chlorine.

*Carbonate* $CO_2$.—This was estimated by direct weighing of the $CO_2$ evolved on boiling the original substance with dilute sulphuric acid in presence of excess of ferrous sulphate.*

In order to check the method, a weighed quantity of Iceland spar was added to a weighed quantity of the manganese sample and the $CO_2$ estimated as above described. The $CO_2$ found after deducting that in the manganese sample (as found by two previous estimations) represented exactly that required by the Iceland spar.

| | |
|---|---|
| 2·065 g Manganese sample containing ·17 per cent. $CO_2$ representing ... ... ... ... ... ... | ·0035 g $CO_2$ |
| ·1020 g Iceland spar representing... ... ... ... | ·0448 g |
| Required ... ... | ·0483 g |

$CO_2$ found ·0483 g.

*$H_2O$ at 105° C.*—Weighed samples were heated in a toluene bath till constant. One estimation was also made by drying in a Hempel desiccator over sulphuric acid in a vacuum. The result obtained by this method was ·15 per cent. lower than that obtained in the toluene bath. As it seemed just possible that even at 105° slight oxidation might take place (as is said to occur in the case of coals) the following experiment was made :—2·164 g was placed in a boat in a tube heated to 102°–105° C. and a current of dry $CO_2$-free air passed for three hours, the water and any $CO_2$ being absorbed by a U tube containing sulphuric acid and potash bulbs :—

| | | |
|---|---|---|
| Loss in weight... ... ... | 19·81 per cent. | |
| Water found ... ... ... | 19·70 „ | |
| $CO_2$ found ... ... ... | ·27 „ | (C. ·07 per cent.) |

From these figures it seems as if slight oxidation may occur, but not enough—at any rate in the time required for estimating the loss at 105°C.—to affect the results to any appreciable extent.

*Combined water and Organic matter.*—The estimation of these was more complicated as, if determined in the ordinary way, the hydrogen of the organic matter combines with the peroxide oxygen and is weighed as water. Indeed, were the water to be estimated as usual and the ferrous sulphate omitted from the $CO_2$ estimation, the analysis would total to about 105 per cent.†

In order to get the values for combined water and organic matter as accurately as possible, the following procedure was adopted :—

1. The loss on ignition was determined in a porcelain crucible, heated first at 105° for an hour or more, then very slowly over a

* The use of ferrous sulphate in estimating $CO_2$ in manganese deposits is mentioned in the "Challenger reports. Deep sea deposits," p. 421, in the account of an analysis by Dr. J. Gibson. It seems that the $CO_2$ was set free by sulphuric acid in presence of ferrous and silver sulphates, the latter being added to prevent the evolution of any chlorine present, and no mention is made of the presence of organic matter.

† In the present analysis when ferrous sulphate was omitted from the $CO_2$ estimation 3·19 per cent. $CO_2$ was found owing to oxidation of organic matter.

free flame, and finally, over the blast till constant. The available oxygen left was then estimated in portions of the residue by the oxalic acid method, the results being within ·1 per cent. of the theoretical amount required to convert the MnO as found in the main analysis into $Mn_3O_4$.

2. Two combustions were made of the original sample, which gave the total carbon (both organic and carbonate, the residue being tested and found free from $CO_2$) and the total water including the water formed by combustion of the hydrogen of the organic matter.

3. To obtain the composition of the organic matter, a portion of the original sample was treated with dilute sulphuric acid in presence of ferrous sulphate. When the manganese had dissolved, the solution was filtered through a hardened filter, the residue washed, first with water containing a little sulphuric acid till free from iron, then with hot water till free from sulphate. The filter was then dried at 105°C. and portions weighed into platinum boats and burnt. As it was found that some of the organic matter dissolved in water, a second weighed portion of the original sample was boiled in water, the solution filtered into a platinum dish, evaporated to dryness, and dried at 105°C. Of this residue, as much as possible was removed to a platinum boat, weighed and burnt. A third portion was treated like the second, the soluble organic matter was weighed after drying at 105°, then ignited and the dish re-weighed, the difference giving the soluble organic matter or at any rate a close approximation to it. The residue not soluble in water was washed back into the beaker, treated with ferrous sulphate and dilute sulphuric acid till the manganese was dissolved, filtered through a weighed filter, dried at 105° and weighed. The filter and residue was then transferred to a platinum crucible and ignited. The difference between the weight of the residue dried at 105° and the ignited residue giving approximately the organic matter insoluble in water.

The dissolved organic matter was ... ... 0·71 per cent.
The undissolved „ „ ... ... 3·12 „

The composition of the respective organic residues calculated on the organic matter found by combustion after deducting the ash left in the boat, as would be done in a coal analysis, was found to be :—

| —— | C. | H. | O & N by difference. | Total. |
|---|---|---|---|---|
| Soluble ... ... ... | 40·4 | 7·9 | 51·7 | 100·0 |
| Insoluble... ... ... | 58·7 | 6·3 | 35·0 | 100·0 |

The percentage calculated on the original sample :—

| —— | C. | H. | O & N by difference. | Total. |
|---|---|---|---|---|
| Soluble ... ... ... | ·29 | ·06 | ·36 | ·71 |
| Insoluble... ... ... | 1·83 | ·20 | 1·09 | 3·12 |
| Total ... ... | 2·12 | ·26 | 1·45 | 3·83 |

The results obtained by combustion of the original sample are:—

| | | | |
|---|---|---|---|
| Total water ... ... ... ... | 28·71 | 28·67 | Mean 28·69 |
| Carbonic acid ($CO_2$) ... ... ... | 8·51 | 8·71 | „ 8·61 |
| Residue in boat ... ... ... ... | 66·11 | 65·79* | „ (65·95) |
| Peroxide O in residue ... ... ... | 6·77 | 6·67 | |
| Hence total solids (Mn as MnO) ... | 59·34 | 59·12 | „ 59·23 |

* This result is low. Possibly owing to some of the fine $MnO_2$ being carried out of the boat with some of the combined water or $CO_2$. In doing "Loss of Ignition" it was found necessary to heat very slowly to prevent loss from this cause.

The result obtained here for total solids is a little lower than that obtained from the sum of the constituents as separately estimated, viz., 59·51.

Now the water driven off at 105°C. was 19·55 per cent. (mean of four estimations of loss at 105°C.), hence combined water formed by the combustion of the hydrogen must be

28·69 – 19·55 or 9·14 per cent.

The $CO_2$ due to carbonates was ·17 per cent. and the total $CO_2$ 8·61 per cent. hence the $CO_2$ due to the organic matter is 8·61–·17 or 8·44 per cent. which represents 2·30 per cent. carbon.

If the composition of the organic matter as found by combustion of the separate residues be taken and the percentage of hydrogen be calculated from the organic carbon found by combustion of the original substance,

$$2{\cdot}12 : 2{\cdot}30 = {\cdot}26 : x \qquad x = {\cdot}282 \text{ per cent. H.}$$

and the total organic matter:—

$$2{\cdot}12 : 2{\cdot}30 = 3{\cdot}83 : x \quad \text{whence } x = 4{\cdot}15$$

·282 per cent. H. gives 2·52 per cent. $H_2O$, hence the combined water is

$$9{\cdot}14 - 2{\cdot}52 \text{ (or } 2{\cdot}32) = 6{\cdot}62 \text{ (or } 6{\cdot}82).$$

The organic matter is probably between 3·83 and 4·15 (mean 3·99) and the combined water between 6·82 and 6·62 (mean 6·72). The following table gives the percentage composition of the organic matter found, and the approximate composition of peat (Percy's Metallurgy, 1875 Edn. Fuels).

| —— | Organic matter in Mn. deposit. | Incipient peat. | Peat. | | |
|---|---|---|---|---|---|
| C. ... ... | 55·32 | 49·9–50·9 | 50·9 | 59·8 | 63·9 |
| H.... ... | 6·59 | 6·5 5·8 | 6·6 | 6·8 | 6·5 |
| O & N ... | 38·09 | 43·6–43·3 | 42·5 | 34·4 | 29·6 |

In soil analyses the humus is often calculated from the organic carbon in the soil on the assumption that humus contains 60·0 per cent. of carbon. (Fresenius, 6th edn., p. 676.) If this be done in the present case:—C. 2·30 per cent. gives 3·83 per cent. of organic matter, whilst the figures obtained are between 3·83 and 4·15.

# APPENDIX IV.

## The Stratigraphical Relations between the Upper Carboniferous Red Barren Measures of Scotland and the Productive Coal Measures.

By C. T. Clough, M.A.

The relation between the barren red strata forming the highest subdivision of the Carboniferous system in Scotland and the underlying Coal-Measures is a question of great economic importance. In the course of the mapping of the Scottish coalfields by the Geological Survey about 40 years ago, some evidence was obtained in Ayrshire and Dumfriesshire which pointed to an unconformability between these divisions. Indeed from certain observations made in the Sanquhar coalfield it was inferred that the Coal-Measures had been faulted and denuded before the red sandstones were laid down.

On account of the economic importance of this question various sections that were formerly regarded as supporting these conclusions have been re-examined within the last few years; and additional mining information relating to the Sanquhar coalfield has been procured. The evidence recently obtained is briefly set forth in this paper.

In the case of the Sanquhar coalfield, in Dumfriesshire, it was inferred, during the original survey, that a fault with a supposed downthrow of 90 fathoms, proved in the Bankhead Colliery, did not penetrate the overlying red sandstones. The presence of coal seams, one of which is two feet thick, and of a seam of blackband ironstone in these red beds is sufficient proof that these overlying red sandstones belong to the Carboniferous formation and not to the Permian or New Red Sandstone.

The large downthrow of this fault, the amount of which has since been proved to be erroneous, and the absence of any satisfactory field-evidence of its continuation in the higher strata north of the pit workings led to the theory that the dislocation was older than the Red Barren measures, and that these latter spread over the fault without being themselves affected by it. Mr. Russell, the Manager of the Sanquhar Collieries Co., Ltd., states that the throw is now known to be about 45 fathoms.* This great decrease in the estimate removes well nigh all the difficulty formerly experienced in explaining the relations of the red sandstones to the underlying strata. For, in many coalfields, faults amounting to 45 fathoms are known to diminish in throw, even within the limits of one conformable series, as rapidly as the dislocation in Bankhead Colliery appears to do.

The hillside which the fault should cross a little north of this colliery is covered with boulder clay, which conceals the outcrops of the rocks and of the fault. But, from the evidence derived

*The change in the estimate is chiefly due to the fact that a seam, formerly called the Daugh Coal, and supposed to lie between the Splint Seam below and the Twenty-inch Coal above, has been found to be merely a part of the Splint Coal. No important coal is now known between the Splint and the Twenty-inch Seams. The distance between these coals is only 25 or 30 fathoms, not 90 fathoms as was formerly supposed.

from various boreholes, Mr. Russell is of opinion that the dislocation is gradually diminishing in amount, and perhaps entirely dying out in a northerly direction.

Mr. Russell also states that he knows no evidence of any unconformity within the Carboniferous beds of the Sanquhar coalfield. He considers the red beds in the brick pit at Sanquhar to be about the position of the Creepie Coal, that is near the top of the Productive Coal-Measures, and that their red colour is due to staining by percolation from overlying Permian or Triassic rocks now removed by denudation. This supposition seems reasonable in view of the occurrence of a patch of lavas of Permian age (?) near this locality.

Reference may now be made to the evidence in support of an unconformity at the base of the Barren Red Measures in Ayrshire (Sheet 14). Near the Burn o' Need, on the east side of the Permian basin beyond Mauchline, the map shows the Carboniferous Upper Red Barren Measures in contact with the Carboniferous Limestone Series, without the intervention of any fault. No mining evidence is available regarding the strata near this junction, and the rocks are so poorly exposed that it is impossible to interpret the structure with confidence. Fossiliferous limestones of the Carboniferous Limestone Series are seen a little way lower down the stream, and on the north-east side of the supposed junction. Near Laigh Burn O' Need, some distance south-west of the junction, beds are exposed which may be confidently referred to the Upper Carboniferous Red Barren Measures, but it is impossible to determine the tectonic relations of the latter to the Carboniferous Limestone Series further north-west. The ground is obscure, and there is ample room for a fault to intervene in the concealed ground. Hardly a mile E.S.E. an important dislocation, striking north-west and with a downthrow to the south-west, has been taken as the north-east boundary of the Red Barren beds in that locality, and it seems quite possible that a branch fault, striking W.N.W. and with a downthrow to the S.S.W., forms the north-east boundary of the Red Barren beds in the Burn O' Need also.

At Auchmillan, still further north-west, in one-inch map 22, a section in an old quarry shows a fine-grained cream-coloured thinly laminated limestone dipping at a high angle, slightly west of south, under white, purple and reddish sandstones mixed with thin bands of hard pale grey and dark grey blaes. Mr. Tait, who specially examined this quarry and the locality to be next described, detected *Spirorbis* in the limestone and *Lepidostrobus* in one of the seams of blaes. Two coal seams, one of which is said to be 20 inches thick, and has been worked in an adit, are also found in these strata. The top bed in the quarry is a reddish purple hard sandstone, with a thickness of about 40 feet exposed, which was taken by the Geological Survey as the base of the Carboniferous Red Barren beds.* No direct evidence of unconformity or overlap at the base of this sandstone is, however, to be observed, and the bed itself is considerably harder than the sandstones usually found in the Red Barren series. Moreover the red colouring is only partial and is most

*Explanation of Sheet 22 (*Mem. Geol. Surv.*,) 1872, p. 21. See also the published six-inch map of Ayrshire 29.

pronounced near joints and bedding surfaces, and sometimes disappears a few inches within the more massive blocks. It seems probable therefore that this sandstone is merely a stained Lower Carboniferous bed resting conformably on the underlying strata. The angle of dip increases at the south side of the quarry, and in the top sandstone amounts to 47°, in a direction slightly west of south. No other rock is seen for a little distance south and south-west of the quarry, but in a burn about 200 yards W.S.W. there are good exposures of soft white and red and purple sandstones with mottled purple and brown clays. These strata are certainly of types common in the Upper Carboniferous Red Barren Measures, but they may quite possibly be separated from the beds in the quarry by a fault. The unusually high dip just referred to of itself suggests disturbance of the strata. South and south-west of the quarry there is much obscure ground through which a dislocation, with a strike at right angles to the observed dip, could pass. Indeed, such a fault, if prolonged in an E.S.E. direction, would cross the Burn O' Need very near the locality where we have suggested the existence of a fault between the Red Barren Measures and the Carboniferous Limestone Series.

In another old quarry, near Longhouse, about three miles W.N.W. of Auchmillan, beds coloured as Carboniferous Red Barren beds in the published six-inch map 23, Ayrshire, are again shown lying directly on the Carboniferous Limestone Series. The bottom bed is a fossiliferous limestone, and the overlying strata are described in the map as "red sandstone, shale and conglomerate." The conglomerate is a peculiar rock with big lumps of ironstone and of hard pyritised blaes, together with pieces of coal and clastic quartz grains, sometimes the size of small peas. It is not at all certain that the ironstone lumps represent pebbles, indeed it seems more likely that they are authigenic. There is no clear indication of unconformity at the base of this conglomerate. The bed overlying it is a hard white sandstone or ganister, about a foot thick, which is succeeded by yellow and white unevenly bedded sandstones with coaly streaks and thin seams of dark grey blaes about 11 or 12 feet in thickness. No red beds are now exposed in the quarry, and if any formerly existed they must have been at least 12 feet above the conglomerate. Even therefore if the conglomerate indicates an unconformity, there is still no clear reason for supposing that it occurs at the base of the Upper Red Barren Measures. It seems more likely to be within the Carboniferous Limestone Series.

The various localities which have now been referred to are, we believe, those in which the evidence in favour of the existence of an unconformity at the base of the Upper Red Barren Measures was formerly considered to be the strongest. On re-examination we must admit that the evidence does not justify this conclusion. It does not, of course, necessarily follow that in certain areas there may not be such an unconformity, but, in view of the evidence now available it may be stated that no break of importance is as yet known at the base of the Upper Carboniferous Red Barren Measures, and that, consequently, wherever these measures occur at the surface, there also we may expect to find the Productive Coal-Measures below.

# APPENDIX V.

## The Geological Structure of Ben Nevis.

By H. B. Maufe, B.A.

From an early period Ben Nevis attracted the attention of geologists, partly because of its outstanding height, but more especially on account of its unique structure. Williams (1) in 1810 and MacKnight (2) in 1811, described the main features in its geology. The flat country at its foot is underlain by gneisses and schists, the lower half of the mountain itself is formed of granite, whilst the upper portion consists of a mass of 'felspar-porphyry,' which is now known to represent a succession of lavas and agglomerates. Both the above-mentioned writers believed that the 'porphyry' overlay the granite, and that the latter in turn overlay

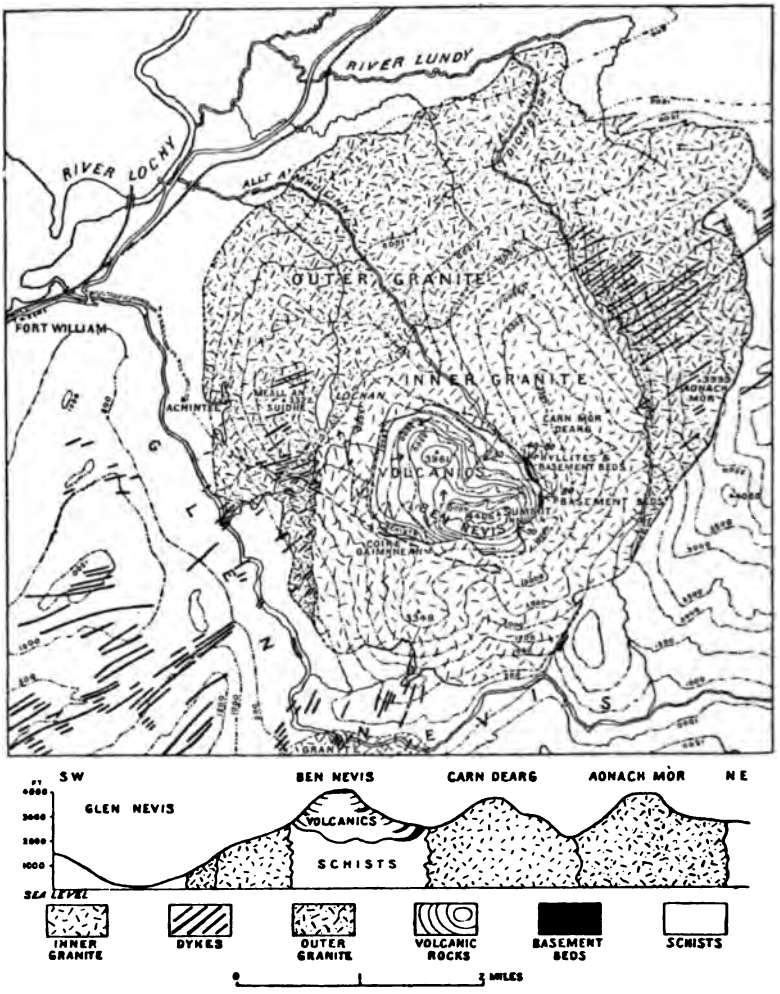


Fig. 5. Geological Map and Section of Ben Nevis.

tne schists. Ami Boué (3) and Thomson (4) made the same deductions from their observations.

On the other hand von Oeynhausen and von Dechen (5) writing in 1830, held that the granite was intruded into the gneisses and schists, and the porphyry of the summit injected into the granite. These conclusions were endorsed by Macculloch (6), Nicol (7), and Murchison and Geikie (8), and received general acceptance for a number of years. Von Oeynhausen and von Dechen observed the main mass of the granite rising up through and truncating the edges of the Highland Schists. They described the variations in composition and texture within the granite itself, noting especially the grey basic facies on the northern margin, which they called syenite, and the fine-grained porphyritic modification found in contact with the summit porphyry. With respect to the last-named rock-mass they commented on the wide occurrence of the brecciated structure so well displayed on weathered surfaces, but erroneously concluded that the whole constituted a single intrusion.

It was always recognised that the junction of the granite and 'porphyry' of the summit was an important one. Williams thought that the 'porphyry' was a distinct stratification overlying the granite. MacKnight thought that the junction was horizontal, but considered that there was a transition between the two rocks. Von Oeynhausen and von Dechen, by following the complete circuit of the 'porphyry,' showed that the junction was everywhere perpendicular. This is clearly the case, and is demonstrable by a study of the course of the junction-line on a contoured map, or of actual sections in the field, in particular, the sections exposed on the north-west shoulder of the hill, and on the ridge which connects the summit of Ben Nevis with Carn Mor Dearg (Fig. 5).

*The Volcanic Series.*—In 1874 Professor Judd (9) embodied a description of the geological structure of Ben Nevis in his account of the Newer Palæozoic Volcanoes of the Highlands. He saw that the "prism of porphyry" constituted a succession of lava-sheets, frequently separated by masses of agglomerate, and that the granite sent veins into and was later than the volcanic series. Dr. Teall (10) has described specimens of the lavas, and showed that they were hornblende-andesites. It is perhaps possible to recognise two varieties, in one of which biotite is abundant, in addition to the hornblende, whilst in the other its place is taken by pseudomorphs after another ferromagnesian mineral, probably a rhombic pyroxene. For the rest they exhibit only those small disparities in composition and texture, which enable one to separate flow from flow, but otherwise of no particular interest.

Frequently the lavas are separated by masses of unstratified agglomerate consisting of angular blocks of hornblende-andesite of all sizes up to 4 feet in length. Mixed with these are blocks of red porphyritic felsite, and occasional pebbles of quartzite and lumps of phyllite. The last-named rocks, evidently derived from the Highland Schists of the neighbourhood, are quite common in the agglomerate which crosses the path up Ben Nevis at a height of 4,000 feet. It is often a matter of great difficulty to separate these

compacted agglomerates from the lavas which show the brecciform structure and enclose xenoliths.

The finer-grained parts of the agglomerate may show a certain amount of stratification, and pass gradually into the coarse-grained sediments associated with them. A specimen of a fine-grained agglomerate has been described by Dr. Mackie (11), but no tuffs showing typical ash-structure have been discovered on Ben Nevis. Typical tuffs are rare in the related lavas of Lorne and Glen Coe.

The sedimentary beds associated with the extrusive series include green sandy shales, dark shales with calcareous bands, and a conglomerate composed chiefly of quartzite pebbles. These rocks closely resemble the corresponding sediments intercalated in the Lower Old Red Sandstone volcanic series of Glen Coe, though on Ben Nevis no fossils have yet been obtained.

Reference has been made already to the relations subsisting between the granite and the volcanic series. It was shown that the former presents a vertical chilled margin against the volcanic group, and does not underlie them directly. The question arises on what formation does the volcanic series rest, if not upon the granite? The answer can be given that they rest unconformably on the Highland Schists in just the same manner as do the extrusive rocks of Lorne and Glen Coe. Outcrops of the Highland Schists were found in two places beneath the Ben Nevis lavas. The larger and clearer exposure is situated in the Allt a' Mhuilinn, a short distance below the foot of the huge precipice north-east of the summit. Here contorted micaceous phyllites crop out beside the stream for a distance of 200 yards. Resting against this in unconformable relation is a basement conglomerate, largely made up of quartzite pebbles, and 8 feet in thickness. Following it comes about 40 feet of indurated black shales with calcareous bands, and upon these lies the lowest lava, a typical hornblende-andesite. Agglomerates and lavas succeed one another up to the summit, the total thickness being probably not less than 2,000 feet, and uninterrupted save for a couple of bands of dark shale.

The basement beds are traceable at intervals for more than half-a-mile along the eastern side of the central massif, and are then cut out in both directions by the rising wall of granite. It is important to note that along the whole line the beds are dipping steeply inwards towards the centre of the volcanic mass. In places, too, the shales are contorted, the sharp folds being frequently fractured and their limbs displaced. In Coire Gaimhnean, on the south-western side of the hill, where schistose rocks are again exposed for a short distance between the granite and the volcanic rocks, the dip of the latter is again inclined inwards at a high angle. Passing from the edge towards the centre of the mass the dip diminishes, sometimes very rapidly, until on the summit ridge the beds are rolling at low angles Evidently the volcanic massif on Ben Nevis has a basin structure, and, surrounded as it is by a ring of granite with vertical chilled margins, it presents a close analogy with Glen Coe (12).

*The Granite Complex.*—The steepness of the granite margin, noticed by von Oeynhausen and von Dechen, is visible in many sections around the edge of the complex, and on a large scale it is patent from an examination of a contoured map showing the granite boundaries. The variations in composition, too, ranging from a more basic variety on the outer margin to an acid kind on the inner edge against the extrusive rocks, have also been described in more or less detail by previous writers. A new point, not altogether without interest in view of the comparison which can be made with the Etive granite, is that the Ben Nevis plutonic complex consists of two distinct masses of different age. The inner rock occupies an oval central area, whilst the outer and older mass is horseshoe-shaped, enclosing the inner granite on every side but the south. The junction is steep and has a varying but slight hade outwards, as is shown by the "veeing" of the junction line down the valleys. The normal rock constituting the outer intrusion is a medium-grained pink porphyritic granite composed of quartz, oligoclase, perthitic orthoclase, biotite and hornblende, with the usual accessory minerals, sphene, apatite and magnetite. The large pink perthite crystals, though appearing to the eye as ordinary phenocrysts belonging to an earlier generation, are not really so. Under the microscope the crystals are seen to possess allotriomorphic outlines, being moulded upon the plagioclase and ferromagnesian minerals, which are frequently enclosed in micropoikilitic fashion. The porphyritic structure, therefore, does not imply two periods of crystallization of felspar. Traced towards the outer margin of the mass the pink phenocrysts dwindle and finally disappear along with the pink felspar in the groundmass. At the same time the ferromagnesian minerals become more abundant and include a considerable quantity of pale green augite. This more basic grey rock forms a rim of varying breadth round the outer granite, being absent only for a short distance on the south-western side of the hill. The schists on its margin show the usual phenomena of contact alteration in a marked degree, the phyllitic rocks passing into a dark compact biotite-hornfels, and the limestones into a marble or lime-silicate hornfels according to their varying purity.

The inner granite is more acid in composition than the outer granite, from which it is readily distinguished by its finer and more even-grained texture, and its smaller proportion of dark constituents. Of the latter, biotite is much the most abundant, hornblende being rare and augite absent. Micrographic intergrowths of quartz and felspar are well developed, and have been the subject of a recent study by Dr. Mackie (13).

The outer margin of this granite is not marked by any peculiar variety, though in this position it frequently changes from the normal pale pink to a grey colour. On the other hand, at the inner margin against the volcanic rocks, it undergoes a remarkable change, passing into a very fine-grained felsitic rock, throughout which are scattered small phenocrysts of felspar and biotite. A streaky flow structure, running vertically parallel to the perpendicular junction, is strongly developed, even more so than the fluidal texture of the neighbouring andesites.

The latter group undergo changes through contact metamorphism similar to those exhibited by andesites in other districts, notably the development of new biotite and hornblende, both in the groundmass and the phenocrysts. The disposition of these altered rocks is quite in accord with what one might expect from their relations with the granite. The altered rocks form a rim round the volcanic massif, and extend up to the level of the summit some hundreds of feet above the highest point now reached by the granite, whilst the alteration dies away towards the centre of the volcanic pile, no matter at what level it is followed in that direction.

*The Dykes.*—As in the case of the Etive plutonic complex, the majority of the dykes associated with the Ben Nevis granite may be classed as porphyrites, though the dominant types are not identical in the two districts. In the dyke-following of Ben Nevis are hornblende-porphyrites, augite-porphyrites, and hypersthene-porphyrites, together with a few acid quartz-porphyries, and basic dykes, which should probably be classed with the hornblende-lamprophyres.

Conclusive proof of the relative age of the granites is afforded by the dykes which are exposed on both sides of the complex. Whilst all of them present chilled margins against the outer porphyritic granite, the majority are cut off by the inner mass. A few only traverse the junction between the granites, but in no case do they penetrate far into the younger one. It is quite clear that the main period of dyke-injection intervened between the intrusion of the granites, as in the case of the Etive complex, but on Ben Nevis it is easy to show that a second dyke-phase followed the intrusion of the younger granite.

There is a significant resemblance, also, in the local concentration of the dykes into a "sheaf" made up of two swarms which extend north-east and south-west respectively from the granite focus. A glance at the map shows how a vast majority lie between two lines which are parallel to the trend of the dykes, and are also tangential to the boundary of the inner granite. The dykes run in a N.E. and S.W. direction, nearly parallel to the trend of the Etive dyke-sheaf. A further point of similarity comes from the fact that they are not disposed radially about the plutonic centre, the southern swarm alone showing a definite, though slight, divergence in trend on opposite sides of the sheaf.

The dyke appearing on the southern margin of the volcanic mass and having a W.N.W trend, is a black olivine-dolerite of Tertiary type. In its westward extension it cuts all the N.E. dykes, and by its distinctive composition and trend emphasizes the difference between the products of our magma and those of later ages.

*General Conclusions.*—Although the age of the volcanic series has not been fixed by the discovery of fossils in the interbedded sediments, the similarity of the latter and of the accompanying igneous rocks to those of Glen Coe and of Lorne, compels us to believe that the lavas of Ben Nevis were erupted in Lower Old Red Sandstone times. Further, it is patent, from the foregoing description, that the structure of Ben Nevis admits of an interpre-

tation similar to that applied to the Glen Coe and Etive igneous centres (12).

The outer granite with its steep walls may be conceived as filling the void created by the gravitational sinking of a subterranean block into the underlying magma. Before the central parts of this column of igneous rock were completely consolidated, tensional stresses acting in N.W.–S.E. direction developed fissures normal to their direction, and the plutonic focus acted as a lateral dyke-injector.

Subsidence, now confined to the central area, again ensued, and was accompanied in complementary fashion by the uprise of the inner granite. But then an event occurred, which, so far as we can tell, is peculiar to Ben Nevis. The roof of the subterranean cauldron gave way, and a block of schists, with its burden of lavas, subsided into the still liquid inner granite. The motion developed a streaky flow-structure in the magma, which itself became chilled against the cool descending mass. The latter, during its subsidence, buckled into its basin shape by reason of the friction on its walls, and its cracked margin, on coming into contact with the magma, was penetrated by veins of granite. The sinking block in its descent must have dropped over 1,500 feet. We are thus led to the conclusion that the lavas of Ben Nevis, in spite of their great altitude, owe their preservation, like those of Glen Coe, to subsidence. The local igneous history seems to have closed with the injection of a few more dykes which pierce the margin of the inner granite.

A point which is not at all clear, is the relative age of the volcanic series and of the older granite. By analogy with other areas we may suppose that the volcanic rocks were extruded first. If this were so, it is perhaps remarkable that not a single dyke has been found cutting through the volcanic rocks. At the same time the schists lying beneath the latter are equally free from dykes, though their outcrop runs at right angles to the swarm of dykes, and is sufficiently long to have included several of them if spaced at average intervals. We can only surmise that the volcanic mass, in its original position, was above the level at which dykes were injected from the subterranean cauldron.

Although a close analogy with the igneous centres lying to the south has been shown to exist, there is not on Ben Nevis that definite evidence of faulting accompanying the uprise of igneous magma which Glen Coe affords, for the occasional brecciation of the schists on the edge of the granite mass cannot be adduced as proof of it. In this connexion we may refer to the deflection of the outcrops of the belt of limestone on the western margin of the granite. The outcrops of limestone, as they approach the granite on either side, advance in a north-westerly direction. At a first glance, the deflection might be attributed to the pressure of the invading magma. When, however, it is realised that the limestone, although packed into tight folds, forms a bed which dips gently towards the south-east, it will be seen that the advance of the outcrop towards the north-west may be due to nothing more than a slight sag of the schists around the margin of the granite. Such a

sag may well have been brought about by the drag at the edge of the block which sank to admit the granite magma.

In conclusion we may allude briefly to the petrological relationship of our plutonic magma. Mr. Lightfoot has determined the silica-percentages in the following rocks from the Ben Nevis complex, the corresponding percentages in the two chief members of the Etive complex being quoted for comparison :—

| | Ben Nevis Complex. Silica Percentage. | Etive Complex. Silica Percentage. |
|---|---|---|
| Inner granite ... ... ... | 71·70 | 71·35 (Starav) |
| Outer granite (normal rock) ... | 67·12 | 68·02 (Cruachan) |
| Grey marginal facies of latter ... | 61·11 | — |

The figures show that the Ben Nevis granites belong to the acid group, whilst the grey marginal facies of the outer granite, containing as it does less than 66 per cent. $SiO_2$, falls into the sub-acid group.

It has been pointed out above that the outer mass is a hornblende-granitite rich in plagioclase. A rough estimate of the relative proportion of the chief constituents shows that the soda-lime felspar (on the average basic oligoclase) slightly exceeds the alkali felspar in quantity. The general equivalence of these constituents at once places the rock in Brögger's monzonite family, as Mr. Harker has pointed out (14), and in view of the silica percentage being higher than 66, the rock will fall into Brögger's acid group, *adamellite*. In the following table the mineral composition of the outer Ben Nevis granite (A) is compared with that of an adamellite from Landsberg (B), given by Brögger (15).

| | A. | B. |
|---|---|---|
| Alkali felspar ... ... ... | 27 per cent. | 35·5 per cent. |
| Soda-lime felspar ... ... | 33 „ | 31·5 „ |
| Quartz ... ... ... ... | 31 „ | 24 „ |
| Melanocratic minerals ... | 9 „ | 10 „ |

A more detailed comparison with typical adamellites shows that the Ben Nevis rock is closely related to them in mineralogical composition and texture, but in the absence of a bulk analysis a closer chemical comparison is not possible.

The granites belonging to the plutonic centres of the district to the south, with which the Ben Nevis granite has just been compared structurally, are very similar in mineralogical composition also. Analyses of three rocks made by Mr. E. G. Radley in the Geological Survey Laboratory are given below, and the analysis of Brögger's adamellite from Landsberg, together with Lindgren's typical granodiorite, is quoted for comparison.

I. Cruachan granite from bed of River Etive, 4 miles above Dalness, Glen Etive (outer granite of Etive Complex).

II. Moor of Rannoch granite from road-cutting ½ mile E.N.E. of Kingshouse Hotel.

III. Starav granite, from stream ¼ mile N. of E. of Coileitir, Glen Etive (inner granite of Etive Complex).

C. Quartz-monzonite (adamellite) from Landsberg, ; quoted from Brögger, " Eruptivgesteine des Kristianiagebietes," II., 1895.

D. Granodiorite from Silver Lake, California ; quoted from Lindgren *Amer. Journ. Sci.*, 4th Series, Vol. III., 1897, p. 306.

| | I. | II. | III. | C. | D. |
|---|---|---|---|---|---|
| Slide No. ... | [14112] | [14110] | [14111] | | |
| $SiO_2$ ... ... ... ... | 68·02 | 66·91 | 71·35 | 68·97 | 67·45 |
| $TiO_2$ ... ... ... ... | ·63 | ·67 | ·47 | — | ·58 |
| $Al_2O_3$... ... ... ... | 14·16 | 15·09 | 13·68 | 14·80 | 15·51 |
| $Fe_2O_3$... ... ... ... | 1·82 | 1·70 | 1·75 | 3·29 | 1·76 |
| FeO ... ... ... ... | 1·95 | 1·95 | ·97 | — | 2·21 |
| MnO ... ... ... ... | ·22 | ·18 | ·18 | — | — |
| (CoNi)O ... ... ... | nt. fd. | nt. fd. | nt. fd. | — | — |
| BaO ... ... ... ... | ·06 | ·05 | ·05 | — | — |
| CaO ... ... ... ... | 2·81 | 3·27 | 1·85 | 3·82 | 3·60 |
| MgO ... ... ... ... | 1·91 | 2·02 | ·84 | 1·15 | 1·10 |
| $K_2O$ ... ... ... ... | 3·92 | 3·16 | 4·36 | 4·53 | 3·66 |
| $Na_2O$... ... ... ... | 3·90 | 4·16 | 3·75 | 2·46 | 3·47 |
| $Li_2O$ ... ... ... ... | nt. fd. | nt. fd. | trace | — | — |
| $H_2O$ at 105° C. ... ... | ·20 | ·14 | ·19 | — | ·14 |
| $H_2O$ above 105° C.... ... | ·56 | ·56 | ·51 | ·70 | ·63 |
| $P_2O_5$ ... ... ... ... | ·16 | ·17 | ·11 | — | ·12 |
| $FeS_2$ ... ... ... ... | nt. fd. | nt. fd. | nt. fd. | — | — |
| $CO_2$ ... ... ... ... | nt. fd. | nt. fd. | nt. fd. | — | — |
| Total ... ... ... | 100·32 | 100·03 | 100·06 | 99·72 | 100·23 |

The Argyllshire rocks containing, as they do, more than 66 per cent. of silica, fall within the acid series. They show that relatively high percentage of calcium which accounts for the abundance of oligoclase and sphene. This high proportion of lime, together with the rough equivalence in the amounts of potash and soda, is characteristic of both adamellite and granodiorite. It is not clear, therefore, from an inspection of the analyses with which of these families our rocks should be grouped. This is due to the fact that all the soda cannot be reckoned to the soda-lime felspar, for some albite is intergrown with the orthoclase in perthitic fashion, and it is necessary to form an estimate of the relative proportions of the soda-lime and alkali felspars. The figures obtained for the proportional amounts of the chief constituents are as follows :—

| | Cruachan Granite. | Moor of Rannoch Granite. |
|---|---|---|
| Alkali felspar ... ... ... | 21 per cent. | 20 per cent. |
| Soda-lime felspar ... ... | 31 „ | 37 „ |
| Quartz ... ... ... ... | 30 „ | 24 „ |
| Melanocratic minerals ... | 18 „ | 19 „ |

For these rocks the soda-lime felspar is decidedly in excess of the alkali felspars. In the Cruachan granite, the outer ring of the Etive complex, the ratio is roughly 3 : 2, whilst in the example from the Moor of Rannoch mass the ratio rises, but does not quite reach 2 : 1. The latter rock, a grey medium-grained hornblende-granitite, is very similar to the granodiorites of the Pacific slopes of the American continent. If, however, we adopt the arbitrary line proposed by Lindgren (16) for the separation of granodiorite from adamellite : that in the former the amount of the soda-lime felspar

is at least equal to double that of the alkali-felspar, the Moor of Rannoch granite will still fall with the adamellites.

The grey marginal facies of the outer Ben Nevis granite containing 61·11 per cent. $SiO_2$ falls into Brögger's sub-acid group *banatite*. A mineralogical comparison with typical banatites justifies the placing of the rock in this category.

Rocks of the type under description from these and other "Newer Granite" masses have frequently been referred to tonalite. According to Becke the typical tonalite is a sub-acid rock (silica 59 per cent.) containing 39·6 per cent. melanocratic minerals and accessories, 57·8 per cent. plagioclase and quartz, and only 2·6 per cent. alkali felspar. So far as the present district is concerned none of the large masses of plutonic rock possess a composition like that of tonalite.

The intermediate and basic members of this rock series need not be referred to further in this place, since none are involved in the Ben Nevis complex. We may, however, point out that the basic member of our series is the well-known kentallenite, which Messrs. Hill and Kynaston have shown to be very similar to Brögger's olivine-monzonite. We see that the acid members of the series on their side are closely related to the acid monzonites, and so far as they vary from typical quartz-monzonite or adamellite, they approximate to granodiorite, that is to say, to the products of a calc-alkali magma, and not to those of an alkali-rich magma.

## LIST OF REFERENCES.

(1.) Williams, J. "The Natural History of the Mineral Kingdom," vol. i, pp. 409 and 469, 2nd Edition, 2 vols., Edinburgh, 1810.

(2.) MacKnight. "On the Mineralogy and local Scenery of certain Districts in the Highlands of Scotland." *Mem. Wernerian Soc. Nat. Hist.*, vol. i, p. 322, 1811.

(3.) Boué, Ami. "Essai géologique sur l'Ecosse," p. 66, Paris, n.d. (circ. 1820).

(4.) Thomson, Thomas. "Outlines of Mineralogy, Geology, and Mineral Analysis." 2 vols., London, 1836.

(5.) Von Oeynhausen and Von Dechen. "Der Bein Nevis am Loch Eil." Karsten's "*Archiv. für Mineralogie*," &c. Band II, pp. 38–54, 1830.

(6.) MacCulloch, J. "Observations on the Mountain Cruachan in Argyllshire, with some Remarks on the Surrounding Country." *Trans. Geol. Soc.*, vol. iv, pp. 117–138, 1817.

(7.) Nicol, J. "Guide to the Geology of Scotland," p. 161, Edinburgh, 1844.

(8.) Murchison, Sir R. I., and Geikie, A. "First Sketch of a New Geological Map of Scotland with Explanatory Notes." Edinburgh, 1861.

(9.) Judd, J. W. "The Secondary Rocks of Scotland. Second Paper. On the Ancient Volcanoes of the Highlands and the Relations of their Products to the Mesozoic Strata." *Quart. Journ. Geol. Soc.*, vol. 30, pp. 291–294, 1874.

(10.) Teall, J. J. H. "British Petrography," pp. 287–8 and 325, London, 1888.

(11.) Mackie, Dr. W. "The Occurrence of Volcanic Tuffs on Ben Nevis." *Trans. Edin. Geol. Soc.*, vol. ix, pp. 69–72, 1907.

(12.) Clough, C. T., Maufe, H. B., and Bailey, E. B. "The Cauldron Subsidence of Glen Coe." *Quart. Journ. Geol. Soc.*, vol. 65, pp. 611–678, 1909.

(13.) Mackie, Dr. W. "The Distribution and Significance of Deviations from the Normal Order of Crystallization, also the Distribution and Significance of Micro-pegmatite in Granites, as illustrated by the Granites of the North of Scotland." *Trans. Edin. Geol. Soc.*, vol. ix, pp. 247–317, 1909.

(14.) Harker, A. "The Natural History of Igneous Rocks." London, n.d. (1909), p. 128, ad fin.

(15.) Brögger, W. C. "Eruptivgesteine des Kristianiagebietes," II, 1895.

(16.) Lindgren, W. "Granodiorites and other intermediate rocks." *Amer. Journ. Sci.*, 4th Series, vol. ix, p. 279, 1900.